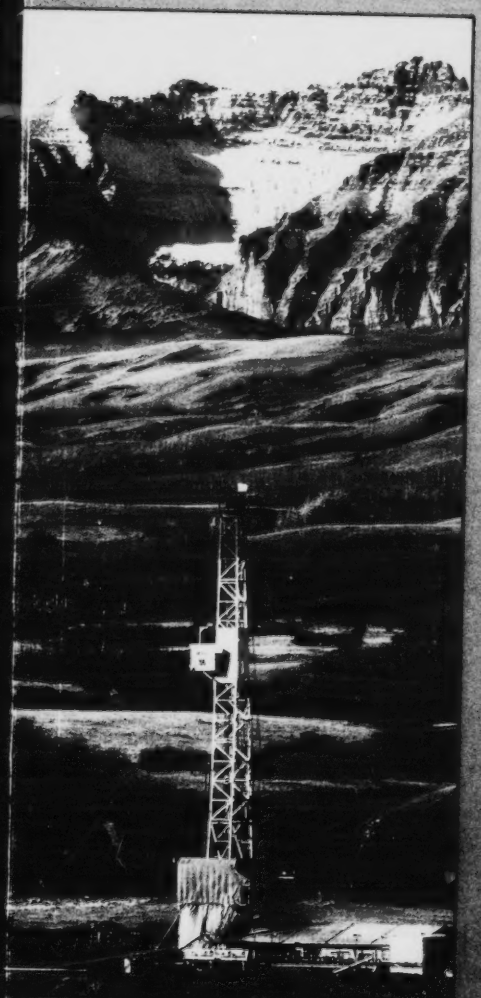
OIL SPILL PREPAREDNESS IN THE UPSTREAM PETROLEUM INDUSTRY



CANADIAN PETROLEUM ASSOCIATION

OIL SPILL PREPAREDNESS IN THE UPSTREAM PETROLEUM INDUSTRY

THE CANADIAN PETROLEUM ASSOCIATION

AND

THE INDEPENDENT PETROLEUM ASSOCIATION OF CANADA

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Gentlemen:

Here is the final report prepared by the Task Force On Oil Spill Preparedness On The Upstream Petroleum Industry.

As you know, this task force was established seven months ago to take an honest look at the abilities of our sector of the industry to respond to and cope with potential oil spills from our operations. We have done that.

While we have concluded that generally we do and have done a good job of protecting the environment and have adequate preventative policies and measures in place, we can do better.

There is no room for complacency in dealing with this most important issue. Our recommendations reflect that. Once implemented, they will do much to assure Canadians of our willingness and ability to deal with this aspect of our business.

I would like to take this opportunity to thank you and your organizations for having the foresight to engage in this most important initiative. I would also like to recognize all those people who worked behind the scenes to make this report a reality.

Yours very truly,

J. J. O'Connor
Chairman Task Force
Oil Spill Preparedness In
The Upstream Petroleum
Industry

EXECUTIVE SUMMARY

This study assesses the Canadian upstream petroleum industry's current state-of-preparedness for dealing with oil spills resulting from exploration and producing activities. It recommends that between $13 and $15 million be spent in research and development, equipment acquisition, and training over the next five years to prevent and control onshore and offshore oil spills more effectively.

The study was sponsored by the Canadian Petroleum Association (CPA) and the Independent Petroleum Association of Canada (IPAC), who represent the majority of companies in the upstream industry. The study uses realistic worst case scenarios to assess the industry's ability to respond to large offshore spills caused by oilwell blow-outs in the Beaufort Sea, Grand Banks, and Scotian Shelf areas during drilling and onshore oil spills from a variety of sources. It does not address future production scenarios in the Beaufort Sea, off the east coast or future exploration activities off the west coast. As progress is made toward future development in these areas, the industry will assess its capabilities for spill response. The issue of spills from marine tankers is the subject of another industry study sponsored by the Petroleum Association for the Conservation of the Canadian Environment (PACE).

The study shows that in the last 40 years the industry has expended a great deal of time and effort to prevent the occurrence of oil spills. As a result of these prevention measures, Canada has experienced no catastrophic oil spills in the course of drilling 385 offshore wells, and the operation of approximately 40,000 producing wells and 37,300 km of gathering and transmission pipelines. In spite of the major efforts taken to date, the industry believes that there is room for improvement. The study recommends that more resources be allocated to improve the training of on-site personnel, to implement better communications within companies and between companies and regulatory agencies, and to continue research in oil spill countermeasures.

The Canadian oil industry's preparedness for oil spill response compares favourably with the best found anywhere in the world. In the past 10 years, over $8 million was spent on research to improve Canadian spill response technology. The recent spills in Prince William Sound, Alaska, and offshore Washington State in the U.S. have provided the impetus for industry to re-evaluate the systems presently in place for spill response.

Onshore, the task force concludes that the industry is prepared and equipped to manage and control most types of spills on land, in small rivers, and in bodies of water. It advises the industry to improve the handling of heavy oil and condensate spills. The study reports that equipment needs to be developed to handle spills into fast moving or ice-congested waters and in muskeg terrain where access is difficult.

The task force believes the offshore industry is also prepared and equipped to handle most blow-out spill incidents in the Beaufort or Scotian shelf areas. In the Beaufort, the industry could

mount a significant and relatively successful spill response with existing equipment and infrastructure. Most oil that remained could be burned with little environmental harm (although sensitive coastal areas may have to be protected). On the Scotian Shelf, very light oil and condensates would evaporate and dissipate naturally with little environmental hazard. In spite of this, there is still a need to upgrade the type and amount of equipment available to operators in these areas.

An oil spill on the Grand Banks - characterized by heavy seas, frequent bad weather, and waxy oil - could, under certain circumstances, mean poor oil recovery conditions. Today, limited logistical support for the open water containment and recovery systems, equipment limitations and the resultant delay in responding could produce a large spill of weathered oil that would be difficult if not impossible to recover. There is a need to improve logistics and equipment in this area.

The conclusions and recommendations of the Task Force are presented in Sections II and III (Offshore and Onshore Working Group Reports) and in Section IV (Summary and Conclusions). The major recommendations have been brought forward and highlighted as part of this executive summary, however, the reader is referred to each specific section for a listing of the detailed conclusions and recommendations.

MAJOR RECOMMENDATIONS:

PREVENTION

* Companies should conduct assessments of all facilities and activities to determine potential spill sources so that preventive actions can be identified and implemented.

* Current leak detection systems should be evaluated, and where deficient, research and development programs should be implemented to improve their efficiency.

* When oil spills occur, they should be evaluated to determine their cause and the results of the evaluation should be incorporated into operating procedures.

EQUIPMENT

* In offshore areas, response capabilities should be consistent with the standards of best practical technology (BPT), and industry should work together with the Canadian Coast Guard to maximize equipment compatibility and effectiveness.

* In onshore areas, equipment requirements at special sites and remote locations should be determined, and where deficiencies are identified, the necessary equipment packages should be developed. In addition, work should be undertaken to ensure compatibility of equipment in the various onshore oil spill co-operatives.

CONTINGENCY PLANNING

* Company and cooperative plans must be reviewed at least annually in conjunction with simulation and communication exercises.

TRAINING

* Companies must recognize that effective oil spill training is not limited to equipment deployment exercises, but should also include spill prevention, contingency planning, and environmental awareness. All staff having responsibilities for spill

response should have specific training related to their functions during an actual emergency.

MANAGEMENT SYSTEMS

* All levels of management should understand their responsibilities for involvement in oil spill response and should participate in crisis management training specifically related to spill response management.

GOVERNMENT LIAISON

* Memoranda of Understanding should be developed between industry and appropriate government agencies to identify areas of responsibility and cooperation during spill response efforts. A single window approach for interacting with government should be identified.

RESEARCH AND DEVELOPMENT

* The industry should continue to support its historical commitment to oil spill research and development activities. Programs should be developed to address the issues (both onshore and offshore) that have been identified as requiring further work.

IMPLEMENTATION

* CPA and IPAC should establish an implementation committee for incorporating these recommendations into member companies activities. This committee will be chaired jointly by senior representatives of CPA and IPAC and will have wide representation from member companies. It will develop mechanisms for ensuring that the recommendations made in this report are dealt with in an appropriate manner by member companies.

ACKNOWLEDGEMENTS

This is to acknowledge the many individuals and companies who participated in this evaluation of oil spill preparedness.

A number of companies who are members of the Canadian Petroleum Association and the Independent Petroleum Association of Canada provided guidance and direction as participants on the Task Force. Mr. John O'Connor, President and General Manager, Mobil Oil Canada, provided leadership both for the Task Force and its Co-ordinating Committee.

Many individuals from a wide variety of companies participated in the two Working Groups that were formed to conduct the onshore and offshore evaluations. In this regard, special recognition is given to Mr. Wayne Wiebe, Petro-Canada Inc., and Mr. Rick Hoos, Amoco Canada Petroleum Company Ltd./Polar Gas Ltd., who were chairmen of these Working Groups.

Three consulting companies provided invaluable support in the preparation of the individual Working Group and Final Summary reports. These were Wotherspoon and Associates; S.L. Ross Environmental Research Ltd. and Dominion Ecological Consulting Ltd.

Among those who contributed significantly to the Task Force effort were Phil Tsui and Tom Cooney, Mobil Oil Canada, Dick Stokes and Gary Miller, Trans Mountain Pipe Line Company Ltd.; Wayne Speller, Petro-Canada Inc.; and Al Kiernan and Bill Tye, IPAC.

Finally, the assistance of a number of individuals from the Canada Petroleum Association is acknowledged as follows: Jim Swiss, Douglas Bruchet, Barry Virtue and Ian Smyth.

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SECTION I

BACKGROUND

SECTION I: BACKGROUND

1.0 INTRODUCTION

This report is a current evaluation of the upstream oil industry's state-of-preparedness for dealing with oil spills arising from onshore and offshore exploration and production activities in Canada and in Canadian waters off the Atlantic and Arctic coasts. The report was prepared by the Canadian Petroleum Association (CPA) and the Independent Petroleum Association of Canada (IPAC) in recognition of public, government, and industry concern about capabilities for dealing with oil spills. The recent spills in Prince William Sound, Alaska and near Vancouver Island are vivid and harsh reminders of the ecological and economic repercussions of complacency and slow response. This report sets out to objectively evaluate the areas in which the industry feels confident of its oil spill prevention and cleanup abilities and those in which it does not. The evaluation deals only with onshore spills and offshore oil well blowouts.

The issue of spills from marine tankers is excluded from this evaluation because it is the subject of an evaluation by the Petroleum Association for the Conservation of the Canadian Environment (PACE). The report does not address the issue of spills from future production activities in the Beaufort Sea or off the east coast, nor does it address the issue of exploration activities off the west coast. If and when future activities occur in these areas, the industry will assess its spill response capabilities.

The industry starts from a position of strength in that spill prevention and response have been increasingly important aspects of operation for many years. Contingency plans are in place to deal with most oil spill emergencies, training in spill prevention and cleanup is widely available to industry employees, equipment and experienced personnel are located throughout the country, and much effort has been expended on research and development of new equipment and techniques for dealing with oil spills. Many of these efforts and programs have been undertaken cooperatively with regulatory agencies at the federal and provincial government levels, such as the Canada Oil and Gas Lands Administration, the Conservation and Protection Branch of Environment Canada, the Canada Newfoundland Offshore Petroleum Board, the Alberta Energy Resources Conservation Board and the National Energy Board. New facilities are subject to development approval by the appropriate regulators, in addition to the guidelines, regulations and statutes governing environmental protection for existing facilities.

Although the Canadian oil industry has expended much effort in spill countermeasures, the wide range of environmental conditions, the limitations of technology, and the risks of human error must, however, be anticipated and accommodated in this regulatory and planning framework. This report is an assessment of how well the oil industry, operating within the existing regulatory and legal framework, would deal with actual oil spill accidents.

2.0 METHODOLOGY

To undertake this evaluation, CPA established the Task Force on Oil Spill Preparedness (TFOSP), comprised of representatives of member companies from both CPA and IPAC, organized into offshore and onshore working groups. Both groups were to determine the current state-of-preparedness of the industry to handle spills in their assigned area (onshore or offshore) and to make recommendations on ways to improve response performance and cooperation within companies and between companies and government. Given the almost infinite variety of environmental conditions and circumstances that might cause and/or accompany an oil spill, the task force decided to use a scenario approach in its evaluations. Each working group determined a number of representative spill scenarios, and industry response was evaluated with respect to each specific set of conditions.

The two groups took different approaches to this part of the task. The **offshore** group chose 12 scenarios related to subsea and above-platform oil well blowouts in the Beaufort Sea, the Grand Banks and the Scotian Shelf. S.L. Ross Environmental Research Ltd., a leader in the field of offshore oil spill contingency planning, was contracted to undertake the evaluation. S.L. Ross described and assessed the current technology available in order to determine the best methods of dealing with specific types of spills and then applied that technology to the individual scenarios. They developed quantitative estimates of the behaviour and characteristics of the hypothetical spills based on modelling and actual experience and estimated predicted recovery given the best practicable response (i.e. assuming use of the best response and support equipment, an ideal contingency plan, and perfectly trained response personnel). This was followed by an estimate of response based on existing capability. Final conclusions on preparedness and recommendations for future action were made by the working group after consideration of the consultant's report.

The **onshore** group, made up of oil industry personnel highly experienced in oil spill response planning, chose 8 scenarios covering a range of production and transportation situations from oil well blowouts to pipeline and storage tank ruptures and heavy oil spills into moving water. The onshore consultant, Paul Wotherspoon and Associates Inc., was contracted to coordinate the evaluation. The onshore evaluation was conducted by assessing responses to questionnaires distributed to all CPA and IPAC members as well as to oil spill co-ops in western Canada, Ontario, Quebec, and the Atlantic provinces. Out of two hundred and sixty (260) companies who were sent questionnaires, fifty-three responded. The CPA and IPAC producing members who responded to the survey represent approximately 70% of the 1988 Canadian gross liquids production. The questionnaire presented a description of each scenario and then asked a series of standard questions to determine how a particular company assessed their ability to respond to the hypothetical situation. A separate questionnaire asked the respondents also to assess their own company's contingency plans. The working group then met to summarize and evaluate the responses to the questionnaires, leading to conclusions on preparedness and recommendations for action and improvements within the industry as outlined in Sections II and III.

SECTION II

OFFSHORE OIL SPILL PROTECTION

SECTION II: OFFSHORE OIL SPILL PROTECTION

1.0 INTRODUCTION

The recent 250,000-barrel spill from the EXXON VALDEZ tanker has created a concern in Canada about the probability of occurrence of spills of this magnitude in Canadian waters and about existing capability to deal with them. Given the present exploratory state of the Canadian offshore oil and gas industry, possible spills of this size could only result from a drilling accident involving an oil well blowout that discharged crude oil into the marine environment over many days. To date, 385 wells have been drilled in offshore areas without a major spill. This report examines the state of preparedness of the upstream oil and gas industry to deal with such spills in the Beaufort Sea, Scotian Shelf and Grand Banks offshore exploration areas. The report does not deal with marine tanker incidents which are the subject of a separate evaluation being conducted by the Petroleum Association for the Conservation of the Canadian Environment (PACE).

1.1 Description of Activities in Canada

Canada's offshore frontier lands have been the subject of considerable interest to the oil and gas industry since the late 1950s and early 1960s. As with other new prospective exploration plays, exploratory drilling in each of the offshore areas of Canada was preceded by several years of geophysical and seismic surveys and resultant data analysis. Since those early beginnings approximately 385 wells have been drilled in Canada's offshore waters and about 65 significant hydrocarbon discoveries have been made.

Offshore Nova Scotia - Scotian Shelf

The first provincial offshore exploration licenses were issued in 1959 covering Sable Island and the surrounding offshore area, and by 1965, the permitted area held by the oil industry covered an area equivalent to twice the size of Nova Scotia's land mass. By early 1967, the whole of the Scotian Shelf was under permit, and after seven years (1960-1967) of acquiring and evaluating seismic data, the first well on the Scotian Shelf (Sable Island #1) was spudded.

In 1971, oil and gas were discovered in the Sable Island E-49 well -- Canada's first offshore oil discovery and the first to actually flow hydrocarbons on drillstem test. During this period, 140,000 km of seismic data were acquired, and 71 wells were drilled. Exploration continued intermittently for several years until 1979, when significant amounts of gas and condensate were discovered in the Venture D-23 well east of Sable Island. The discovery contained almost as much gas as all other discoveries made since 1969 combined and brought the promise of early development and production in the Sable Island area.

Between 1983 and 1988, 49 wells were drilled under new exploration agreements, most with assistance from the Petroleum Incentive Program. With world oil prices plummeting, exploration activity declined steadily during 1986 and has been at a low level since. By 1988, a total of 125 wells had been drilled and 22 significant discoveries had been made. A number of regulatory steps have been taken to move the Venture Gas Project closer to development. The oil play encompassing the Cohasset and Panuke fields has produced very encouraging results which could eventually lead to development of a small oil field using existing technology.

Offshore Newfoundland

Drilling began offshore Newfoundland in 1966 with Tors Cove D-52 and Grand Falls, H-09. Both wells were abandoned, and drilling stopped until 1971. Forty wells had been drilled by the end of 1974, but only one - Adolphus 2K-41 - had a significant oil show. Four wells were drilled off Labrador during this period and resulted in two gas discoveries - Bjarni and Gudrid H-55. It was not until 1979 that a major discovery was made at Hibernia P-15 - the 60th well drilled off Newfoundland. Since 1980, well starts climbed to a high of 12 in 1984 and dropped to a low of 2 in 1989.

Prior to the Hibernia discovery, drilling activity concentrated on the southern Grand Banks and the Labrador Shelf. Since then, exploration efforts have been focused on the northern Grand Banks. Terra Nova K-08 was spudded in 1983 and found a major oil-bearing reservoir. In addition to Hibernia and Terra Nova, other potential fields include: Whiterose, North Ben Nevis, Hebron, Ben Nevis, Fortune, South Tempest, and Nautilus.

From 1966 to the present, 136 wells have been drilled off Newfoundland with 19 declared as Significant Discovery Areas.

Mackenzie Delta-Beaufort Sea

The search for petroleum in the Mackenzie Delta area began in the late 1950s, spurred on in part by promising results from exploratory drilling in both the Norman Wells area to the south and Yukon Territory to the west. Geophysical surveys were initiated in 1958 and 1959. A number of companies obtained rights to large tracts of land in the delta area and exploratory drilling began in 1962. By 1968, 38 wells had been drilled in northern mainland areas, but none had discovered significant amounts of oil or gas. Those early wells, however, did confirm and extend interpretations of the region's geology. In 1968, oil was discovered in Prudhoe Bay on the Alaskan Beaufort Sea coast, and that even spurred further seismic and exploration activity in the delta.

Exploration moved to the shallow nearshore waters of the Beaufort Sea in 1973 when the first artificial island was constructed for use as a drilling platform. Other drilling followed in the shallow water off the delta, and as drilling experience as gained in nearshore areas, drilling efforts were extended to deeper waters. Drilling in the Beaufort Sea using drillships was initiated in 1976. To date, approximately 170 wells have been drilled in the southern Beaufort Sea, and 26 have been classified as Significant Discovery Areas, including Amauligak, Tarsuit, Adlartok, Issungnak, Pitsiulak and Kopanoar.

Arctic Archipelago

Concerted efforts to determine the oil and gas potential of Canada's Arctic Archipelago began in 1955 when the Federal Government initiated geological surveys in the region. Efforts by private interests to explore the region began several years later. The results of early surveys suggested that the potential for hydrocarbon deposits in the area was high, and in 1961, a well was drilled at Winter Harbour on the south coast of Melville Island. At about the same time, a tar sand deposit, estimated to contain 16 million cubic metres (100 million barrels) of oil, was discovered on the northern side of Melville Island. Exploration drilling moved north and east in 1969, into a geological area known as the Sverdrup Basin. In 1974, Panarctic pioneered offshore drilling in the High Arctic through the use of man-made ice islands, and a total of 34 ice islands were constructed to provide drilling platforms in the offshore during the long winter periods.

Approximately 180 wells were drilled in total, resulting in the discovery of a significant number of large, highly productive gas fields and a few smaller oil fields, the most significant to date being the Bent Horn field on Cameron Island. This field has produced oil for summer season tanker delivery to northern sites and southern Canada on an annual basis since 1985.

Offshore West Coast

In 1963, geological mapping programs began on the Queen Charlotte Islands, and between 1963 and 1967, detailed seismic surveys were conducted in the offshore areas. A 14-well offshore drilling program was started in 1967 and completed in 1969. Eight wells were drilled in the Hecate Strait-Queen Charlotte Sound area and six wells were drilled off the western coast of Vancouver Island. No significant hydrocarbon accumulations were encountered in any of the offshore wells, but several small and encouraging hydrocarbon shows were recorded. Hydrocarbon shows were noted in the form of oil staining in rock samples or a minor build-up of natural gas in the drilling mud during drilling.

In 1972, the federal government imposed a moratorium to prevent crude oil tankers from travelling through Dixon Entrance, Hecate Strait and Queen Charlotte Sound enroute from the Alyeska pipeline terminal at Valdez, Alaska. Subsequently, a Federal Order-In-Council indefinitely relieved existing offshore permit holders from obligations for exploration and placed a moratorium on further drilling.

In 1981, British Columbia declared an Inland Marine Zone in waters under provincial jurisdiction and placed an indefinite moratorium on offshore exploration in Johnstone Strait, the Straits of Georgia and Juan de Fuca. At the same time, the Province indicated that a public hearing would be required before exploration in the Hecate Strait - Queen Charlotte Sound area would be allowed to proceed.

In 1984, an Environmental Assessment and Review Process (EARP) panel was appointed to conduct a public review of the environmental and socio-economic effects of renewed exploration and to determine the terms and conditions under which it might proceed. The panel reported its findings and recommendations in April 1986, concluding that exploration drilling could proceed subject to a number of terms and conditions. The B.C. and federal governments are currently evaluating the report in order to conclude a "Pacific Accord" which could allow further exploration to proceed.

2.0 PROBABILITY OF OFFSHORE SPILLS

2.1 Sources of Offshore Oil Pollution

Large spills from offshore oil and gas operations may cause significant damage on a local or regional scale. However, it is worth noting that such events contribute only a very small fraction of the total oil discharged into the world's oceans. The U.S. National Academy of Sciences (NAS 1985) has estimated that about 3.2 million metric tons of petroleum enter the world's oceans annually (see Table 1). Oil and gas operations contribute about 1.5% of the total oil discharged and tanker spills contribute 12.3%, based on data from 1975 to 1980. More recent statistics (1980-1985) place the tanker figure at about 4% (IMO 1986). This decrease in tanker accidents resulting in spills is certainly due to a decrease in the volumes transported over the past several years, but it also related to improved management on the part of tanker owners and operators.

2.2 Probability of Large Spills (>150,000 barrels) from Oil Well Blowouts

Since the latest cycle of offshore drilling began in 1973, Canada has never experienced a major crude oil spill. In U.S. waters, only two oil well blowouts of moderate size (>50,000 barrels) have occurred. If a large or major spill is defined as 150,000 barrels or larger, five such spills have occurred in the history of worldwide offshore drilling. To establish a database, all blowout spills greater than 10,000 barrels are listed in Table 2.

Spill frequencies are best expressed in terms of a risk exposure factor based on the number of wells drilled or billions of barrels of oil produced. On a world-wide basis, it has been estimated that 36,633 offshore wells were drilled from 1955 to 1980 (Gulf 1981). Assuming a drilling rate of about 2000 wells per year since 1980, it is estimated that approximately 53,000 wells have been drilled to date. Over the entire history of offshore drilling, this translates into a frequency of oil well blowout spills greater than 150,000 barrels of 9.4×10^{-5} spills per well drilled or 1 such spill for every 10,600 wells drilled.

The spill rate can also be expressed in terms of the amount of oil produced from offshore areas of the world. The cumulative total oil produced offshore to the end of 1988 is estimated to be about 80 billion barrels (Gulf 1981, NAS 1985, MMS 1986). On this basis, the frequency of large spills from offshore oil well blowouts has been 0.063 spills per billion barrels of oil produced.

From 1973 to 1989, 385 offshore wells were drilled in Canada, an average of 24 wells per year. Currently, less than ten wells per year are drilled offshore in Canada. Using the international spill frequencies, the chances of a large spill in Canada are therefore 2.26×10^{-3} spills per year or one spill every 443 years ($24 \times 9.4 \times 10^{-5}$). Expressing spill frequencies in terms of oil produced is not relevant at this time as no offshore areas of Canada are in production, but once production starts, spill frequencies of about 0.063 spills per billion barrels of oil might be expected. For example, for a production rate of 50 million barrels or 0.05 billion barrels per year, the spill rate would be 3.2×10^{-3} large spills per year, or one spill every 313 years. The projected spill frequencies are summarized in Table 3 for drilling rates of 10 and 30 wells per year.

Table 1: Input of Hydrocarbons into the Marine Environment (source: NAS 1985).

Source	Best Estimate (million metric tons per year)	Percentage (%)
A. Natural Sources		
Marine seeps	0.2	6.2
Sediment erosion	0.05	1.5
Total Natural Sources	**0.25**	**7.7**
Offshore Production	**0.05**	**1.5**
B. Transportation		
Tanker operations	0.7	21.5
Dry-docking	0.03	0.9
Marine terminals	0.02	0.6
Bilge and fuel oils	0.3	9.2
Tanker accidents	0.4	12.3
Nontanker accidents	0.02	0.6
Total Transportation	**1.47**	**45.2**
C. Atmosphere	**0.3**	**9.2**
D. Municipal and Industrial Wastes and Runoff		
Municipal wastes	0.7	21.5
Refineries	0.1	3.1
Nonrefining industrial wastes	0.2	6.2
Urban runoff	0.12	3.7
River runoff	0.04	1.2
Ocean dumping	0.02	0.6
Total Wastes and Runoff	**1.18**	**36.3**
TOTAL	**3.25**	**100.0**

Table 2: Large Oil Spills from Offshore Oil Well Blowouts

Area	Reported Spill (bbl)	Date	Operation Underway
Mexico	3,000,000	1979	Exploratory drilling
Dubai	2,000,000	1973	Development drilling
Iran[1]	?	1983	Production
Mexico	247,000	1986	Workover
Nigeria	200,000	1980	Development drilling
North Sea/Norway	158,000	1977	Workover
Iran	100,000	1980	Development drilling
USA Santa Barbara	77,000	1969	Production
Saudi Arabia	60,000	1980	Exploratory drilling
Mexico	56,000	1987	Exploratory drilling
USA S. Timbalier 26	53,000	1970	?
USA Main Pass 41	30,000	1970	Production
Trinidad	10,000	1973	Development drilling

[1] The Iranian Norwuz oil well blowouts in the Gulf of Arabia, which started in February 1983, were not caused by operational accidents but were a result of military action during the Iran/Iraq war.

These derived spill frequencies are based on spills in countries (except Norway) that generally have less stringent standards than those in the US and Canada. For example, it is known that the largest oil spill in history, the 1979 Ixtoc I oil well blowout in the Bay of Campeche, Mexico, was caused by drilling procedures that are not practised in Canadian waters and which are totally contrary to Canadian regulations and to accepted practices within the international oil and gas industry.

Table 3: Expected Frequency of Large Platform Spills in Canada (>150,000 bbl)

Platform Spill Rate	
10 wells drilled/year	30 wells drilled/year
9.4 x 10-4 (1 spill in 1000 years)	2.8×10^{-3} (1 spill in 300 years)

3.0 DESCRIPTION OF OFFSHORE SPILLS - BLOWOUTS

3.1 Source Behaviour of Spills

Oil well blowouts can occur in two ways:

i) the drilling platform moves off site or is destroyed during the blowout, and oil is discharged from the seabed and rises through the water column to the surface (e.g. 1979 Ixtoc I blowout in Bay of Campeche, Mexico); or

ii) the platform maintains its position during the accident because it is undamaged or bottom-founded, and oil discharges into the atmosphere from some point on the platform above the water surface some distance downwind (e.g. 1976 Ekofisk blowout in the North Sea).

Oil well blowouts, both subsea and above-surface, generally involve two fluids - crude oil and natural gas. The volume ratios of these two fluids are a function of the characteristics of the fluids, and the pressure and temperature of the geological reservoir. The natural gas, being a compressible fluid under pressure at reservoir conditions, provides the driving force for an uncontrolled blowout. As the well products flow upwards, the gas expands, finally exiting at the well-head at velocities of up to hundreds of metres per second. At this point, the oil makes up only a small fraction of the total volumetric flow.

3.1.1 Subsea Blowouts

The oil and gas released from a subsea blowout pass through three zones of interest as they move to the sea surface. The jet zone is the zone of high initial velocity at the well-head exit. In this highly turbulent environment, the oil is fragmented into droplets ranging from 0.5 to 2.0 mm in diameter (Dickens and Buist 1981). Water is also entrained in this zone, and a rapid loss of momentum occurs a few metres from the discharge location.

Immediately above in the buoyant plume zone, momentum is no longer significant, and buoyancy becomes the driving force moving the oil-water mixture toward the surface. In this region, the gas continues to expand because of reduced hydrostatic pressures, and oil and water in its vicinity are entrained in the flow and carried to the surface. Although the terminal velocity of a gas bubble in stationary water is only about 0.3 m/s, velocities in the centre of blowout plumes can reach 5-10 m/s because of the pumping effect of the rising gas in the bulk liquid. The water surrounding the upward-moving gas is entrained and given an upward velocity, which is then increased as more gas moves through at a relative velocity of 0.3 m/s and so on. When the plume becomes fully developed, a considerable quantity of water containing the oil droplets is pumped to the surface.

In the surface zone, the rising water and oil flow away from the centre of the plume in a radial layer. At the surface, the oil coalesces in this outward flow of water and is spread into a slick at a rate much faster than conventional oil diffusion or spreading rates. The resulting slick takes on a hyperbolic shape when subjected to a natural water current, with its apex pointing up-current. The sizeable quantities of gas released during these blowouts enter the atmosphere at the 10-15 m diameter turbulent bubble area above the plume and disperse through atmospheric turbulence.

The resultant width and thickness of the slick, combined with the flowrate, determine the

physical limitations and effectiveness of spill control operations and thus potential environmental impact. S.L. Ross (1986) has developed a mathematical model of slick dimensions resulting from a subsea blowout. A very large blowout in a water depth of 80 m flowing at 30,000 barrels of oil per day (BOPD) will produce a slick only about 0.07 mm thick which, if non-viscous, will disperse very quickly under average sea state conditions. However, oil released from a subsea blowout may form a viscous water-in-oil emulsion containing up to 80% water (and as little as 20% oil) (Ross et al. 1979). This would increase the thickness and volume of the oil fluids at the surface by a factor of five.

The dimensions of slicks resulting from blowouts involving gas condensates cannot be plotted on the same axes because flow rates are generally low and gas-to-oil ratios very high. Predicted slick dimensions for two condensate blowout flowrates and three different water depths are shown in Table 4. Generally, slick thicknesses are much less for condensate blowouts than for crude oil blowouts.

Table 4: Predicted Slick Dimensions for Subsea Condensate Well Blowouts

Condensate flowrate (m^3/day)	Gas/Oil ratio (m^3/m^3)	Water depth (m)	R (m)	Y (m)	Z (m)	X (um)
36 (225 BOPD)	18,000	20	2	165	1040	1.6
		80	8	455	2860	0.6
		200	21	880	5530	0.3
156 (980 BOPD)	18,000	20	2	270	1710	4.4
		80	8	750	4700	1.6
		200	21	1450	9100	0.8

KEY:
R - Boil radius
Y - Upstream extent
Z - Slick width
X - Slick thickness

3.1.2 Above-Surface Blowouts

Oil released above the water surface during a blowout from an offshore platform will behave quite differently from a subsea discharge. The gas and oil will exit at a high velocity from the well-head and will be fragmented into a cloud of fine droplets. The height that this cloud rises above the release point will vary depending on the gas velocity, oil particle size distribution and the prevailing wind velocity. Based on limited data from actual incidents, it is reasonable to assume that the cloud will rise to a point about 25 m above the well-head. The fate of the oil and gas at this point is determined by atmospheric dispersion and the settling velocity of the oil particles. The oil will 'rain' down, with the larger particles falling nearer the release point.

If the gas is blowing through the derrick or some other obstruction, the larger oil droplets may agglomerate on the obstruction and flow down onto the rig floor.

The width and thickness of slicks of oil and condensate 'raining' out of the plume have been modelled. In this model, the width of the slick is not a function of flowrate, but only of the lateral atmospheric dispersion coefficient (i.e. stability class). Slicks resulting from a platform or surface blowout are much thicker and narrower than slicks from subsea blowouts and are thus easier to control and recover using conventional spill cleanup equipment.

3.2 Fate of Spilled Oil

Once the oil from a subsea or above-surface blowout spreads across the water surface, it is swept away by winds and currents and undergoes a number of weathering processes. The most important phenomena that influence spill impact and control are spreading, movement, and persistence of the oil.

3.2.1 Oil Spreading

Oil spreading increases the size of the affected area, and thereby increases the difficulty of containing the spill and the probability that greater proportions of biological populations may contact the oil. Several models of oil spreading behaviour and its dependence on oil properties and environmental conditions have been developed over the last two decades (Blokker 1964, Fay 1969, Mackay et al. 1980). All of these models relate the properties of oil (density, viscosity, and interfacial tension) to its spreading on calm water. The more comprehensive models also include an oceanic diffusion term to describe spreading behaviour in more realistic sea conditions.

The model developed by Mackay et al. (1980) includes the observation-based assumption that as the slick spreads, it forms thick patches that contain most of the oil volume but cover only a small portion of the area. These patches are surrounded by thin sheens (in the 1 um range) that contain a small portion of the total oil volume over a wide area.

Some oils do not spread on water as described above. This category includes oils that have a pour point that exceeds the ambient temperature (i.e. the temperature at which the oil does not flow is higher than ambient). The pour point of an oil can be naturally high (e.g. Grand Banks crude oils) or may be high as a result of evaporative losses of hydrocarbons during exposure to the environment.

3.2.2 Oil Movement

In addition to the natural tendency of most oils to spread over a water surface, surface slicks may be transported away from the spill site by water currents. These currents usually combine residual movement and wind-induced surface movement. Mackay (1984) reports that the rate of oil slick movement may be increased by a factor of 3.5% of the wind speed measured 10 m above the water surface. However, the final vector of oil movement depends on the combined influence of residual and wind-induced surface currents. Over relatively long distances, Coriolis forces (due to the earth's rotation) cause the direction of wind-induced slick motion to deviate 10-15° to the right of the wind direction in the Northern Hemisphere. In nearshore marine waters, the movement of oil slicks is also affected

by tidal currents, river outflows and longshore currents.

3.2.3 Oil Persistence

The persistence of oil on the water surface is controlled primarily by three processes:

i) evaporation;
ii) natural dispersion of oil into the water column;
iii) the formation of water-in-oil emulsions.

The first two processes remove oil from the water surface, but compete with the formation of emulsions which tends to stabilize the oil slick and reduces losses from the surface.

Evaporation: Evaporation is one of the most important processes that affects the properties and therefore the behaviour of spilled oil. It is also the most intensively studied and predictable process (Mackay 1984). The evaporation rate of an oil slick is controlled or affected by :

- the temperature of the oil and the air;
- the surface area of the oil in contact with air;
- the thickness of the oil;
- wind speeds;
- the concentration and vapour pressure of the individual components of the oil (perhaps the most important factor).

Emulsification: When most crude oils are spilled at sea, they tend to form water-in-oil emulsions (occasionally referred to as 'chocolate mousse' or simply 'mousse'). Emulsification occurs in the presence of mixing energy such as that provided by wave action. Seawater is incorporated into the oil in the form of microscopic droplets, resulting in several undesirable changes to the oil. First, there is a significant increase in the bulk volume of fluid that must be dealt with. Secondly, there is a marked increase in fluid viscosity (up to 100-fold). The much higher viscosities greatly inhibit the natural dispersion of oil and make the application of chemical dispersants less effective.

The mechanisms and rates of oil emulsification are poorly understood. Through some mechanism, the mixing energy associated with waves causes small water droplets to become entrapped in the oil layer. This process may occur in a manner similar to the natural dispersion of oil droplets into the water column, as both are mixing phenomena that require wave action. However, the two processes are competitive. Emulsification tends to inhibit dispersion because it increases the oil's viscosity and thus its persistence on the water.

Natural Dispersion: The natural dispersion of oil into the water column is the most important process controlling the long-term fate of oil slicks at sea. In conjunction with evaporation, this process reduces the volume of oil on the water surface, thereby influencing the potential extent of surface and shoreline contamination.

Although natural dispersion is a poorly understood process, it is known that oil/water interfacial tension, oil viscosity, oil buoyancy and slick thickness all interact to affect the ability of a particular oil to disperse naturally. Sea state is also an important factor controlling the rate and amount of dispersion. Even light, non-viscous oils do not disperse rapidly under calm conditions. On the other hand, even the heaviest, emulsified oils can disperse over a period of time in heavy seas when breaking waves are present.

3.3 Cleanup Implications of Blowout Spill Behaviour

Oil slicks from oil well blowouts will be relatively narrow close to the blowout site and very thin (less than 0.1 mm thick) because the oil is introduced to the water surface at relatively low feed rates (10,000 BOPD or 1 m^3/min). The narrowness of the slick permits a large proportion of the oil to be concentrated and collected at source using containment and recovery devices, if weather or sea state conditions permit.

4.0 OIL SPILL COUNTERMEASURES

4.1 Approach

Oil well blowouts are easier for contingency planners to handle than some other types of spills because the exact location of the potential spill is known, and considerable effort can be undertaken to develop a state-of-preparedness to deal with a spill should one occur. Protection priorities, currents, wind patterns, spill movement predictions, etc. can all be considered in advance. Furthermore, although the total quantity of oil that can be released is large, the amount of oil discharged per day is relatively low and can be recovered or treated with a modest amount of equipment or materials. Finally, the oil slick at the blowout site is generally in a fresh fluid state, which benefits all control techniques.

Because an offshore oil spill spreads rapidly, the primary strategy for spill control is transportation of cleanup equipment to the incident site as quickly as possible while the spill is more concentrated in area and therefore more manageable. If environmental conditions are moderate and appropriate equipment is on site, the spill can be contained by physical barriers and then removed by skimmers and pumps or perhaps by burning. During high sea states, containment and removal methods will not be feasible. The oil will be mixed naturally with seawater or dispersed into the water column, and chemical dispersants can be used to enhance these processes. In summary, the primary methods for dealing with an offshore oil spill are containment, skimming and removal, burning and dispersion.

If these at-source containment and removal techniques fail, the oil will spread, and in general, after many hours of spreading, the slick can no longer be controlled physically because of its vast area, or chemically dispersed because of its viscosity. At that stage, movement of the slick must be tracked, its degradation monitored, the likely destination of the remaining oil predicted, and as many priority coastal areas as possible protected against possible onshore movement of the oil. Any areas that do become oiled must then be cleaned up and restored.

It is clear that the countermeasures operation at the accident site is the determining factor in preventing or minimizing environmental damage. Although a well-planned and managed shore-based operation can do much to reduce environmental damage and cleanup costs, control efforts at source are of primary importance.

Oil spills in ice require a different approach. Ice generally acts as a natural containment barrier to an oil spill's flow and spread, and the oil is usually sufficiently thick that it can be burned in-situ. Growing ice during winter also causes oil to become encapsulated into the ice, thereby preventing oil from harming vulnerable wildlife for the remainder of winter. In spring, the encapsulated oil migrates to the surface through brine channels. At this point, in-situ burning techniques can again be employed to effectively

eliminate large quantities of the remaining oil. Combustion techniques are therefore the primary countermeasure for oil spills in ice, particularly in the Arctic.

These general approaches for dealing with major offshore spills in Canada appear to be straightforward, but the actual control and cleanup of large spills is an exceedingly complex task. The following section outlines the current technology on which oil spill countermeasures are based.

4.2 Offshore Oil Spill Countermeasures Technology

The oil spill countermeasures in common use today can be grouped into the following categories:

- subsea containment
- fireproof booms
- in-situ combustion
- physical containment and recovery
- chemical dispersion
- shoreline protection and cleanup
- disposal of oil spill cleanup debris.

4.2.1 Subsea Containment

The optimum solution for environmental protection during an oil well blowout is subsea containment. This involves placing a hollow device over the blowout at the sea bed to contain the uprising mixture of oil and gas or to channel it to the surface where it can be burned or otherwise removed. The 'Sombrero' was a subsea containment device constructed hurriedly and deployed during the Ixtoc I blowout in Mexico. It failed because of poor hydrodynamic design, but subsequent research has developed the concept further (Meikle 1981). Currently, the concept shows promise for application in shallow water, such as the drilling waters in the southern Beaufort Sea and on the Grand Banks of Newfoundland. The polar ice pack in the Beaufort and rough seas off Newfoundland present problems in installation and operation of the device that have yet to be resolved. The concept is still at the early research stage and thus must be discounted as a solution for controlling potential blowouts in Canada in the immediate or near future.

4.2.2 Fireproof Boom

A unique fireproof containment barrier was developed to the prototype stage by the Canadian Beaufort oil industry (Buist et al. 1983). The original purpose of the device was the containment of oil for in-situ combustion, primarily downstream but relatively close to the surface release point of a subsea blowout. Its use makes a one-step oil removal process possible in open water. The fireproof boom has undergone rigorous evaluation in both nearshore and offshore conditions and promises to offer a valuable method for dealing with an oil well blowout during reasonable weather conditions.

This device is constructed entirely of stainless steel with corrugated panels interspaced between rigid flotation sections to allow wave-conforming action. Considerable research was required to identify material for the boom that could withstand the 950°C of continuous heat evolved when crude oil is combusted.

The fireproof boom is designed to operate in a sea state of 4 on the Beaufort wind scale and to survive Beaufort 5 conditions. Field testing indicated that fresh crude oil can be burned at very high efficiencies (over 99%) within the boom.

In regular non-breaking moderate waves, no effect on the oil combustion process has been noted.

Other fireproof booms are also available commercially now, such as the one developed by 3M Corporation (Allen and Fischer 1988). Although these do not have the strength and seakeeping capabilities needed for open-ocean use, they are readily available and reasonably priced and could be used during relatively calm offshore conditions.

4.2.3 In-Situ Combustion

Oil discharged under an ice cover will ultimately appear in surface melt pools as the oil migrates upward through brine channels and the ice melts downwards (Dickens and Buist 1981). The in-situ combustion of oil trapped or contained in ice is viewed as a prime removal technique in the Arctic. Oil ignition involves a one-step removal process (as opposed to containment, mechanical recovery, transfer, concentration and disposal) and is seen as particularly applicable to spills in remote regions. Burning rates of several tons per hour are possible, depending on the approach used.

An air-deployable igniter has been tested and used successfully in Canadian Arctic ice conditions (Dickens and Buist 1981, Meikle 1981, Allen 1987). This model consists of a wire mesh holder containing a layer of gelled kerosene and a layer of solid propellant suspended between two metallic cylinders. A fuse of preselected length is used to initiate the combustion process. A slightly larger igniter developed for Environment Canada by the Defence Research Establishment at Valcartier features a delayed-firing mechanism (Meikle 1981).

The Helitorch ignition system has also been developed for use in the Arctic (Allen 1987). The Helitorch simultaneously releases and ignites discrete globules of gelled hydrocarbons (100-500 ml in volume) onto an ignition target such as an oil slick. The unit is suspended by cable from a helicopter, and release of burning fuel is controlled by the helicopter pilot. Field tests have demonstrated that with release heights of up to 20 m, burning gelled gasoline can survive splash effects upon impact and continue to burn for several minutes. Floating oil in layers 2.5 to 13 mm thick has been successfully ignited even in the presence of broken ice, subfreezing temperatures, and winds up to 30 km per hour.

4.2.4 Physical Containment and Recovery

The most common approach to the removal of oil spills involves the use of booms and skimmers to contain and subsequently recover the oil.

Booms: Oil spill booms are the most important tools in any spill cleanup program because the efficient operation of any oil removal technique requires that the oil be contained and concentrated. Booms are generally the first equipment mobilized at the scene of a spill and the last to be removed.

Booms available commercially today can survive in rough seas, are compatible, and are relatively easy to deploy. Construction techniques have moved away from solid flotation to air inflatable chambers to reduce weight, offer optimum wave conformity, and improve storage and handling characteristics. Bottom tension and external tension lines are used because they give the boom superior wave-tracking characteristics.

Regardless of design, however, booms will contain oil spills effectively in water current

velocities below 50 cm/sec (1 knot). In faster currents, oil tends to build up in front of the boom and can be released under the skirt. Booms and skimmers are ineffective in rough seas. Winds of 20 knots or sea states of 4 are considered to be the upper limit before failure. This is of particular concern in Canada's rough east coast waters.

The B.P. Vikoma Boom system is used by government and industry for east coast open-ocean duty in Canada. It is an air-inflatable boom stored either in a fibreglass hull or in a shipboard container. Each unit contains about 500 m of 1 m high barrier which can be deployed in a matter of minutes to either completely encircle or otherwise contain oil for subsequent mechanical pickup. The boom is maintained in an upright position by a below-surface water-filled chamber, and an upper air-filled cylinder provides buoyancy. The boom system is rugged, has excellent wave-conforming characteristics, and is ideal for fast response situations. Large vessels are required to deploy and position the booms, and these can also serve as platforms for skimming the contained oil. However, continuous power is required to maintain the deployed configuration, and loss of flotation will result if the fabric is torn, as might happen in the high wind and wave conditions expected in rough offshore waters. The Vikoma Boom has been used successfully in the past, and with the experienced trained personnel available in Canada, it could be used satisfactorily in some offshore spill situations.

Other boom systems are available for offshore containment. Generally, such equipment is rugged and reliable and does not need auxiliary mechanical gear or motorized components to ensure its operation and survival. Some systems use solid foam elements for flotation, and these booms can maintain containment despite some damage. Individual sections are usually 15 to 60 m in length and can be replaced if required. None of these booms has been designed to be used in the presence of ice. The Arctic Boom developed for the Beaufort Sea could be transported to a spill site if mechanical booming was considered appropriate in conditions of ice-infestation. The boom has a V-shaped configuration and houses a solid flotation chamber so that ice can be deflected without endangering the integrity of the boom structure. The boom material is a neoprene-impregnated conveyor belting product noted for its high tensile strength, durability and suitability for cold-weather situations. Smooth sides minimize ice collection while aluminum vertical stiffeners and lead weight ballasts maintain the boom in a vertical position. About 730 m of this boom are presently stockpiled in the southern Beaufort Sea area.

Many other smaller, commercially available booms could be used in a large spill operation to protect nearshore areas and biologically sensitive resources. These smaller booms usually have a maximum height of 0.9 m or less and are constructed of solid or air-inflatable flotation chambers. Literally tens of thousands of metres of such booms are stockpiled across the country, and in the event of a large offshore spill, as much boom as required could be transported to the spill site.

Availability of sufficient boom is thus unlikely to be a limiting factor in containing and controlling a large spill. The logistics of moving the boom to the spill site, vessel availability, and availability of trained personnel who have experience in operating the equipment present a more important problem. However simple the concept, containing an oil spill on water, especially in high seas or currents, is an extremely difficult and time-consuming task. Highly motivated and

competent crews are essential to ensure the most successful operation.

4.2.5 Skimmers

The ultimate objective of a spill cleanup operation is the removal of oil from the environment. Mechanical devices to recover oil spills in specific situations, such as rivers, coastal areas and the open seas, are available in various sizes ranging from large, self-contained and self-propelled vessels down to small units that can be handled and operated by a single person. The selection of suitable oil recovery devices usually includes such considerations as the anticipated location of use, the properties of the oil, the environmental conditions, and the availability of necessary support systems.

A countermeasures operation for a large oil spill would probably involve the use of a range of skimming devices. In general, the larger units would be used at the source of the spill in open sea conditions, and the smaller units would be used in nearshore areas where oil had pooled or had been contained.

Skimmers can be classified according to their basic principles of operation. Methods incorporating oleophilic (oil-attracting) surfaces are among the most effective for use in the offshore environment. The largest and most expensive skimmer of this kind presently in Canada is the FRAMO ACW-400. Five of these skimmers are located across the country, three owned by the Canadian Coast Guard and two owned by the oil industry. The units cost about $500,000 each, can be operated in a range of sea states, and are designed for high volume recovery of oil contained in booms. The disc skimming component is backed by a weir system and has the capacity to process from 100-200 m^3/hour, depending on oil type and wave conditions. The ACW-400 is a self-contained unit that can be installed quickly on a range of vessels from harbour tugs to offshore supply vessels.

The FRAMO TRANSREC skimmer system has been developed recently and may have particular application for large spills of viscous oil. The system has been widely used in Norway and is designed to be mounted on the deck of a supply vessel. It uses a weir skimming principle, with optional 'drop-in' conversion modules that allow disk or rope-mop skimming if required in particular conditions. Recovery rates range from 100-300 m^3/hour of oil and highly viscous emulsions. A self-contained positive displacement transfer pump delivers collected oil back to the tending ship.

A large number of devices are available for nearshore operations. The Canadian-manufactured Morris Industries MI-30 skimmer is in widespread use in Canada. It uses the rotating disc principle and has been shown to be effective on contained stationary slicks of fresh and slightly weathered oil. Small skimmers like the MI-30 function best in calm sea conditions and have some ability to recover oil in debris-infested waters.

The Oil Mop is also popular and effective on contained spills in nearshore areas. It is constructed of strands of polypropylene woven into a rope. Oil preferentially adheres to the rope mop and is squeezed off by a wringing system. The unit functions well in limited wave conditions and with some debris infestation. It can process a range of oils similar to the disc-type skimmers. The Oil Mop can be adapted to any vessel and can function as a self-contained rapid-deployment system that can be transported quickly to a spill site. Both the MI-30 and the Oil Mop skimmers

would be considered for use as primary response hardware for nearshore operations in the event of a large offshore spill.

The Slicklicker, used during the Arrow spill in 1970, is also widely available for spill response. It can be utilized effectively to remove contained oil, including very viscous products, by simply transferring product on a rotating belt to any storage container. Much development work has been focused on improving the capability of this Canadian-made skimmer to move very heavy oils in large volume. Its use is limited to calm water.

4.2.6 Chemical Dispersion

In general, chemical dispersants are used when mechanical recovery methods are not feasible. When sprayed onto an oil spill, dispersants decrease the interfacial tension between the oil and the water, thereby assisting the sea in breaking up the oil and dispersing it into the water column. The oil, in the form of droplets, is diluted quickly minimizing its immediate impact and accelerating natural biodegradation processes.

Dispersants can be applied to oil slicks by surface vessels or aircraft. When surface vessels are used, dispersion efficiency can be increased if the vessels supply additional mixing energy to the oil/dispersant layer by using devices such as breaker boards, but response times and application rates are low because of the relatively slow speed of the vessels. The use of aircraft greatly increases application rates, but mixing energy is restricted to that supplied by the ocean itself. Aerial application is considered the most promising approach for dealing with large batch oil spills at sea where vast areas of surface are covered by oil quickly and immediate response is crucial.

However promising dispersants are for treating offshore oil spills, three major questions must be addressed before their use is considered practical and acceptable. These questions are related to the effectiveness of existing dispersant products, the toxicity of dispersants, and logistical considerations.

Dispersant Effectiveness: The most important question today regarding dispersants is whether they are actually effective in dispersing large fractions of oil even when applied properly. Dispersants are **ineffective** on heavy oil slicks, water-in-oil emulsions, and any slick that by weathering or cold temperature is rendered viscous. However, for relatively non-viscous oils, dispersants have been found to have consistently high efficiencies in small-scale laboratory tests, and it was assumed for years that dispersants were similarly effective in the field. Recently however, extensive analysis by Environment Canada (Fingas 1985, 1987, 1988) has put this assumption into serious question. Others feel that dispersants are reasonably effective. Recent investigations by the U.S. National Research Council (1989) based on a few carefully planned, monitored and documented field tests (McAuliffe et al. 1980, 1981), stated that some dispersants have been shown to be effective on some oils, and that dispersants should be considered as a potential first response option to oil spills, along with other response options (Butler 1989).

While the question of dispersant effectiveness remains unresolved, it is prudent to assume at this time that dispersants 'might' be effective on relatively non-viscous oil spills (e.g. viscosities < 2000 mPas), and that they should be used on a trial basis for Canadian offshore spills that involve such non-viscous oils. If they prove to be

ineffective, their use should be discontinued and other cleanup approaches utilized. Considering the oil spill scenarios discussed later in this report, dispersants would only be used on Beaufort Sea oil spills, as Grand Banks crude oil is considered too waxy and viscous for effective chemical dispersion. Dispersion would not be required for gas condensate spills as condensates disperse quickly naturally.

The controversy over dispersant effectiveness highlights the need for further research to develop products that are clearly effective on a range of oil spill types.

Dispersant Toxicity: The use of chemical dispersants involves environmental 'trade-offs'. Dispersants are used to remove oil from the ocean surface to prevent damage to wildlife and shorelines, but at the expense of introducing oil into the water column and threatening organisms located there.

Oil, even in very thin slicks, is known to be harmful to birds and mammals, so the advantages of protecting them through the use of dispersants are clear. The effects of chemically dispersed oil on water column dwellers is less clear, but a picture of the effects of their use in deep waters is emerging from recent extensive research in this area. The most recent generation of dispersants is relatively non-toxic, and hence, the effects on water column dwellers are due almost entirely to the effects of the dissolved and particulate oil (Mackay and Wells 1981, Sprague et al. 1981, Trudel 1978). When dispersants are applied, the resultant concentration of oil in the water column is initially high (in the parts per million range), but it is believed that these concentrations decrease rapidly to low levels (in the parts per billion range), so that sublethal effects (e.g. tainting) become the main concern.

The use of dispersants in Canada is closely regulated because of the potential biological effects. A dispersant must meet government standards (Environmental Protection Service 1984) before it can be used in Canada, and further government approval is required before dispersants are actually deployed in any particular spill situation. General and specific methods have been developed in Canada to facilitate decision-making on use of dispersants. These include a Dispersant Use Handbook (S.L. Ross 1986) which outlines general procedures to be followed in determining environmental trade-offs associated with dispersant usage, and a specific emergency-use protocol for considering the use of dispersants on oil spills in the Beaufort Sea. The system has yet to be tested in an actual spill situation or under simulated conditions. It is similar to a more sophisticated, computerized system developed for U.S. operations in the Gulf of Mexico (S.L. Ross 1989).

Logistical Considerations: The successful use of chemicals in a large countermeasures operation requires that the proper application equipment, trained personnel and a well-conceived contingency plan be available. Stockpiling of sufficient dispersant at strategic locations and a well-rehearsed logistics plan for delivering the chemical to the spill site are crucial. Information on the world-wide stocks of dispersant is limited, but it is believed that there is enough available to deal with very large offshore oil spills, assuming that the chemicals can be collected and delivered to the site quickly.

Response time is a particularly important factor because, as time passes, evaporation, spreading and formation of water-in-oil emulsions make treatment more difficult. This is not a key factor in low flow oil well blowouts because the slicks at the blowout site are fresh and non-viscous (if emulsions are not formed). For batch spills,

however, chemical dispersants are most effective when employed early in the spill. An efficient decision-making process is therefore an essential prerequisite.

Use of dispersants on a large scale in the Ixtoc I oil well blowout was considered successful and demonstrated the feasibility and advantages of aerially applied dispersants as a countermeasures technique.

4.2.7 Shoreline Protection and Cleanup

In the event of a large offshore oil spill, the major concern is that winds and currents may drive the oil into nearshore areas and onto land where significant environmental damage can occur and where cleanup costs escalate. Many offshore spills never reach land, but tend to move further offshore and/or breakup quickly and dissipate. A strong case can be made for this happening with some potential oil spills from offshore platforms in Canada. Nevertheless, other oil spills in the ocean, especially those that occur in nearshore waters, have the potential to cause extensive contamination of shorelines.

In such cases, because it is impossible to protect and immediately clean up all sections of shoreline, it becomes necessary to establish priorities so that available and effective response countermeasures can address those areas where mitigative action is most necessary. Development of appropriate response priorities involves a careful evaluation of the potential threat posed by a spill (based on socio-economic, aesthetic and ecological factors) and the availability of time, manpower and equipment to do the job. Although in many cases the establishment of priorities can only be made at the time of the spill, much can be done to alleviate decision-making problems by proper contingency planning.

In Canada, the approach has been to develop, as specifically as possible, shoreline cleanup and protection strategies before a spill happens. Very detailed site-specific shoreline protection and cleanup manuals have been developed for all offshore areas of Canada where oil and gas activity is currently underway (southern Beaufort Sea, Grand Banks, Scotian Shelf).

In summary, the management and decision-making aspects of a shoreline protection and cleanup operation can be very difficult for a large spill, especially when considering that the entire operation may have massive manpower and logistics components. In general, shoreline cleanup is a labour intensive operation because the most commonly used and efficient techniques still involve oil removal by shovels, rakes, garbage bags and the like.

4.2.8 Disposal of Oil Spill Cleanup Debris

Once oil and contaminated material have been collected from water and shorelines, they must be disposed of in an environmentally acceptable manner. Solid debris may include floatable material (seaweed, wood), sorbent material (straw, foam) or sand, gravel and rocks depending on the location of the spill and the cleanup methods used. In general, this material can be dumped or incinerated. Conventional disposal techniques include:

- landfilling with municipal solid wastes at dumps near the cleanup site;
- burial at specially selected sites;
- deposition on land with little or no soil cover;
- use in construction projects as road base;
- land cultivation (land spreading, land farming).

All of these disposal techniques present a threat of contamination to the surrounding environment, especially through leaching into groundwater

supplies. Considerable research and development have been undertaken to identify proper and safe disposal procedures (e.g. U.S. EPA 1977, Petroleum Association for the Conservation of the Canadian Environment 1978). In southern Canada, the identification of acceptable landfill or burial sites for a given incident is the responsibility of provincial and local authorities. In the Arctic, Environment Canada has designated areas along the Beaufort Sea coast as potential landfill disposal sites in the event of a major spill cleanup (Hardy 1979). Guidelines specify site selection, design, construction and reclamation for both summer and winter operations. Approximately 217 landfill disposal sites and 223 temporary storage sites have been identified for the shoreline extending from the Alaska-Yukon border to Cape Bathurst.

In general, in both northern and southern Canada, approved landfill sites are limited because of technical, environmental or social reasons, and as a result, incineration of cleanup debris has been researched as an alternative disposal technique. Its advantages include use in isolated areas and areas where landfill is not possible, high rate of throughput, less complex logistics, and reasonable cost. The following burners and incinerators have been developed primarily in Canada:

* Saacke Burner: unique portable burner moved by large helicopter that can process about 500 barrels of 60% oil-in-water emulsion per day, makes it possible to burn liquid oil almost anywhere.

* Swirlfire Burner: self-contained package , diesel-powered, oxyacetylene torch needed for ignition, units to process 40 m^3/day could be moved by medium-sized helicopter. Not yet used for oil spill purposes, but has been used to dispose of waste solvents with up to 50% water content.

* Air Curtain Pit Incinerator: developed by the Prairie Regional Oil Spill Containment and Recovery Advisory Committee (PROSCARAC) for use in remote regions (CPA 1980); high capacity blower pushes air down into a prepared earthen pit; diesel driven; burns 20 tonnes of oily waste per hour with minimal or no auxiliary fuel supply.

* Cleanfire Incinerator: stainless steel firebox with forced air-cooled walls; comprised of two modules weighing 1700 kg in total; extensively tested and used worldwide; can be used to dispose of a variety of oiled solid material; burns up to 0.9 tonnes of solids per hour; attempts to burn 6-10 tonnes of viscous oily liquids per day resulted in overheating of the firebox and production of unacceptable quantities of black smoke.

* Reciprocating Kiln: low-cost disposable incinerator that can be improvised using readily available skills and materials; burned up to 2 tonnes per our of oiled beach sand in tests; modified version used to incinerate heavy bunker oil and oiled debris from the Kurdistan spill. In 1980, Environment Canada contracted development of a version that could be built in sections and transported to the site by helicopter.

4.3 Monitoring and Surveillance

Keeping track of the location of the spill is an important component of any spill control operation. Aircraft and radio-tracking buoys are usually used for surveillance. Direct visual observation from aircraft and ships is the most obvious way of determining the extent and movement of a spill. This would be undertaken

during all phases of a Canadian spill cleanup operation by fixed wing aircraft and helicopters operated by government and industry. When visual tracking is not possible because of fog or darkness, radio-tracking buoys designed to stay with the drift of an uncontained slick moving with currents and wind can be used. The buoys can be monitored from land, fixed-wing aircraft or ships. Transmission can continue for two to three weeks and can be received from 15 km away on the water and 45 km in the air.

More sophisticated remote sensing methods, using several sensors operating in different spectral bands, can also be used to detect and map oil slicks. Sensors are available from private Canadian companies, but none is configured permanently for oil spill detection and monitoring.

Tracking is an important countermeasure for oil spills in moving ice in the Arctic or off the east coast. ARGOS positioning buoys have been used successfully in the past to track moving ice in the Arctic. Signals transmitted from the ARGOS mobile beacons are received by several satellites on polar orbits. The data are accessed by interrogation from telemetry stations, or users with a VHF direct receiving station can receive information directly on their own beacons.
The concept of dropping a simple short-range radio marker onto ice has been developed by several Canadian firms. Impulse radar, specifically synthetic aperture radar (SAR), is also available to provide accurate information on ice movement. In this case, repeated overflights must be made and deflectors on the ice sighted using the SAR.

4.4 Response Organizations

The importance of oil spill contingency planning and training cannot be overemphasized. The best equipment and techniques will not be effective in dealing with a large offshore oil spill in Canada unless the response to it is well-planned and organized and involves well-trained and experienced operators. A core of experts in government and industry, trained in the latest technologies and supported by the best equipment, must be able and prepared to respond on a 24-hour basis to major spills wherever they happen.

It is clear that a very large oil spill in Canadian waters could be a national calamity requiring that resources from all parts of the country be brought to bear on it. The response would call for co-operation between industry, many government departments, regional and local authorities and other interests. It follows that this cooperation should be evident at the contingency planning level, before a spill occurs.

The Canadian Coast Guard (Transport Canada) and the oil industry are the two organizations with the responsibility and resources to control oil spills in Canada although the petroleum regulator (COGLA) is designated as the overall co-ordinator of government responses to oil spills from blowouts. The Coast Guard's primary mandate is to respond to vessel-source oil spills, using a small but dedicated staff of marine emergency and oil spill control officers and workers, and an impressive spill control equipment arsenal worth millions of dollars. It represents the government's chief hope in dealing with a major marine emergency. The Coast Guard would be actively involved in any oil spill control operation if it were in the national interest to do so, as would probably be the case for any very large spill, regardless of who caused it.
The oil industry is also actively involved in oil spill control, but from a different perspective. The oil companies have developed the capability to respond to offshore oil spills, especially their own, and have amassed a stockpile of spill control equipment throughout the country that

approaches the Coast Guard's in size and capability. Some of this equipment is in the hands of individual companies, and the rest is operated and maintained by contractors and cooperatives on behalf of the companies. Although this equipment is not as centrally controlled as that of the Coast Guard, recent cooperative efforts on the part of several major oil companies indicate that at least some portions of it, along with equipment from outside the country, could be made available to assist with a major oil spill anywhere in Canadian waters.

Both the Coast Guard and the oil industry have oil spill control organizations across the country that are designed to deal with spills resulting from their operations. The Coast Guard has five regional offices, each of which can generally handle small to moderate sized spills without outside assistance or control. Similarly, within the oil industry, there are a number of regionally based organizations, either company-controlled or industry-operated, that are designed to handle most anticipated spills without outside help. Potential problems might exist where a spill is too large to be handled satisfactorily by the local or regional forces and when the scope of the problem demands national attention, coordination and effort.

5.0 EVALUATION OF RESPONSE CAPABILITY AND PREPAREDNESS

5.1 Choice of Oil Spill Scenarios

To evaluate response capability and preparedness, twelve scenarios are examined in which hypothetical oil well blowouts occur in the Beaufort Sea, the Grand Banks and the Scotian Shelf - the three main offshore areas of Canada where exploration and drilling are now taking place - under a variety of environmental conditions. Within the spectrum of oil-well blowout possibilities, spill behaviour and cleanup potential can vary dramatically with the properties of the oil involved, environmental conditions (temperature, sea state, fog, ice daylight hours etc.) and other factors peculiar to the locations and methods involved in the drilling.

Spill Type

In each of the three geographic areas, scenarios were developed for subsea blowouts (in which the drilling platform moves off the site or is destroyed in the blowout)and for above-surface blowouts (in which the platform maintains its position and oil is discharged into the atmosphere from a point above the platform). Spill behaviour is dramatically affected if discharging hydrocarbons are ignited and partially burned, and this possibility will also be considered, but not in separate scenarios.

Spill Size

In the Beaufort Sea and on the Grand Banks, it would be possible, assuming virtually every prevention mechanism failed at the wrong time and standard blowout control procedures were blocked by ice or storms or were otherwise obstructed, to have a blowout in the range of 30,000-40,000 barrels of oil per day (BOPD) for 100-200 days. Without completely ruling out this highly remote possibility, discharge of 10,000 BOPD for 45 days was chosen as a more reasonable situation for wells on the Grand Banks and in the Beaufort Sea. The total quantity discharged (450,000 barrels) would still represent the third largest oil-well blowout in history and be about twice the size of the recent EXXON VALDEZ tanker spill and about six times larger than Canada's most significant spill ever, the ARROW tanker in 1970. For the Venture gas

development field offshore Nova Scotia, the liquid product of a well blowout would be gas condensate, and its worst-case flow has been calculated to be 1000 BOPD (Mobil Oil 1985). In each case, the implications of the spill being larger or of longer duration are also discussed.

Regional Factors

Each scenario takes into account the different properties of oil discovered in the Beaufort Sea, Grand Banks and Scotian Shelf and the different environmental conditions that prevail in each area in different seasons. For example, Grand Banks oils are 'high pour point' oils which become extremely viscous and highly persistent once spilled in cold water, whereas the gas condensates found off Sable Island are very volatile products which evaporate and dissipate quickly once spilled. Environmentally, there are vast differences between the regions in terms of ice conditions, sea states, temperatures, etc. These environmental factors will influence spill behaviour and countermeasures and must be considered separately.

Summary

Twelve detailed scenarios were chosen, representative of the Canadian situation, and the details of each are summarized in Table 5. All spills are 10,000 BOPD for 45 days. A gas condensate spill off Sable Island is assumed to flow at 1000 BOPD for 45 days. Environmental conditions are also summarized in Table 5. The properties of the oil in each area are based on information supplied by industry operators and is consistent with other sources (Dome et al. 1982, Gulf Canada 1985, S.L. Ross 1984, 1985).

5.2 Approach to Evaluation

5.2.1 Steps in Evaluation

The following steps were followed in evaluation of industry's regional response to each scenario:

* each spill is described in detail in terms of the behaviour and fate of the oil in the environment;

* a quantitative analysis is performed to determine the best response and cleanup effort that could be expected for each spill, in terms of oil recovery, burning or dispersing. This 'best practicable' response assumed the use of the world's best response and support equipment, an ideal contingency plan and the use of perfectly trained response personnel;

* a similar quantitative analysis is conducted to determine industry's response and cleanup capability based on an assessment of existing plans, personnel and equipment;

* the industry's existing capability is compared to the best practicable capability to identify deficiencies that can be corrected by acquisition of better equipment or development of better contingency plans and training programs.

5.2.2 Quantitative Evaluation

Cleanup performance is assessed by estimating the proportion of the spilled oil that be dealt with using the standard countermeasures (described

Table 5: Summary of Oil Well Blowout Scenarios

Scenario #	Spill Location	Blowout Type	Oil Type	Blowout Flowrate BOPD	Gas-to-Oil Ratio m^3/m^3	Water Depth m	Season	Wind m/s	Air Temp. °C	Water Temp. °C	Hours Daylight	Visibility % > 1 km	% Time waves< 1m & < 2m with period 6s	Ice Cover
1	Beaufort	Subsea	Amauligak	10,000	135	20	summer/ fall	5	0	0	16	85	70	0-5/10ths open water grey/white
2	Beaufort	Subsea	Amauligak	10,000	135	20	winter	4.2	-25	ice	N/A	N/A	N/A	10/10ths
3	Beaufort	Above-sea	Amauligak	10,000	135	N/A	summer	5	7	5	24	85	70	0
4	Beaufort	Above-sea	Amauligak	10,000	135	N/A	winter	4	-25	ice	0	N/A	100 (ice)	10/10ths (1st year)
5	Grand Banks	Subsea	Hibernia	10,000	267	80	summer	7	17	65	55	0		
6	Grand Banks	Subsea	Hibernia	10,000	267	80	winter	11	-2	3	9	92	12.5	0
7	Grand Banks	Above-sea	Hibernia	10,000	267	N/A	summer	7	17	12	17	65	55	0
8	Grand Banks	Above-sea	Hibernia	10,000	267	N/A	winter	11	-2	3	9	92	12.5	0
9	N.S. Offshore	Subsea	Venture Condensate	1,000	17,000	22	summer	7	15	15	16	81	58	0
10	N.S. Offshore	Subsea	Venture Condensate	1,000	17,000	22	winter	11	1	5	10	95	16.5	0
11	N.S. Offshore	Above-sea	Venture Condensate	1,000	17,000	N/A	summer	7	15	15	16	81	58	0
12	N.S. Offshore	Above-sea	Venture Condensate	1,000	17,000	N/A	winter	11	1	4	10	95	16.5	0

previously) under the various environmental and oil type conditions expected for each scenario. These figures are summarized for all scenarios in Table 6.

Best Practicable Response is used to determine the maximum amount of the oil that could be removed from the environment under the prevailing conditions using the best technology and personnel. In open water, the best practicable response in each scenario is assumed to involve three containment /recovery/ transfer systems requiring six supply boats, 2250 m of offshore boom, and three high-rate recovery systems. The powerful FRAMO TRANSREC system was chosen as the best recovery device available worldwide because of its high recovery rates and ability to work in high sea states and with highly viscous oil.

The total fraction of oil removed is estimated using the following general formula:

$F = F_{RT} \times F_{TRP} \times F_{SI} \times F_{SE}$

where

F = total fraction of oil removed

F_{RT} = response time factor. It is assumed that it is reasonable to expect a 48-hour response and set-up time before operations can commence. For a 45-day blowout, $F_{RT} = 43/45 = 0.956$.

F_{TRP} = fraction of the time that response is possible considering the environmental factors of daylight, visibility (fog), and sea state. Operations are assumed possible when there is daylight, visibility greater than 1000 m, and waves less than 1 m for all wave periods or less than 2 m for wave periods of 6 seconds or greater. The F_{TRP} values for all regions and seasons are summarized in Table 7.

F_{SI} = fraction of slick intercepted by booms. Assuming a boom length to boom swath width ratio of 3:1, the maximum swath width is 750 m for the best practicable case. F_{SI} is simply the applicable boom swath width divided by the thick slick width close to the blowout source. For the situation where the slick width is less than the swath width, the fraction intercepted is 1.0, i.e., the best practicable booming arrangement can intercept all oil flowing from the blowout.

F_{SE} = skimmer efficiency factor. This includes all factors associated with inefficiencies in the skimming system because of pumping, downtime, losses, etc. The F_{SE} is the fraction of the oil encountered that can be processed by the applicable skimming system. Three TRANSREC systems can process 300 m^3/h if viscosity is less than 100,000 cp. If viscosity if greater than 100,000 cp, the three systems can process 225 m^3/h. These recovery rates are for total fluid. When emulsions are involved, the total oil recovered can be estimated from the percentages of oil and water in the emulsion.

TABLE 6: SUMMARY OF MAXIMUM OIL REMOVAL EFFICIENCIES

Scenario Number	Description	Total Oil Discharged (bbl)	Oil Evap. & Disp. Initially	Skimming (bbl)	Further Oil Removed by: Ignition + Burning (bbl)	Chemical Dispersion (bbl)	Evaporation (bbl)	Oil Left After Removal Operations (bbl)	Oil Spill Dissipation Time* (hrs)
1	Beaufort; subsea; summer/fall.	450,000	240,000	57,120	13,000	18,400	42,000	79,480	19
2	Beaufort; subsea; winter.	450,000	0	0	306,000	0	80,640	63,360	?
3	Beaufort; above-surface; summer.	450,000	157,000	169,650	0	50,570	15,280	57,500	38
4	Beaufort; above-surface; winter.	450,000	72,000	0	280,000	0	66,400	31,600	?
5	Grand Banks; subsea; summer.	450,000	112,500	37,370	0	0	0	300,370	775
6	Grand Banks; subsea; winter.	450,000	76,500	7100	0	0	0	366,400	>1344

Table 6 continued

Scenario Number	Description	Total Oil Discharged (bbl)	Oil Evap. & Disp. Initially (bbl)	Skimming (bbl)	Further Oil Removed by: Ignition + Burning (bbl)	Chemical Dispersion (bbl)	Evaporation (bbl)	Oil Left After Removal Operations (bbl)	Oil Spill Dissipation Time* (hrs)
7	Grand Banks; above-surface; summer.	450,000	225,000	54,000	0	0	0	171,000	880
8	Grand Banks; above-surface; winter.	450,000	198,000	10,080	0	0	0	241,920	1344
9	Scotia Offshore; subsea; summer.	45,000	45,000	0	0	0	0	0	<1
10	Scotia Offshore; subsea; winter.	45,000	45,000	0	0	0	0	0	<1
11	Scotia Offshore above-surface; summer.	45,000	45,000	0	0	0	0	0	<1
12	Scotia Offshore; above-surface; winter.	45,000	45,000	0	0	0	0	0	<1

* Oil Spill Dissipation Time is the time taken for oil discharged at the blowout site to lose 95% of its original volume through evaporation and natural dispersion.

Note: If Beaufort Sea blowout number 3 and 4 occur on a gravel island or bottom - founded structure, and is ignited at source, all 450,000 barrels of oil will be consumed in the fire, resulting in no oil pollution of the surrounding environment.

Table 7: F_{TRP} - Fraction of Time that Response is Possible Considering Environmental Factors

Region/Season	Fraction Daylight	Fraction Visibility Operational	Fraction Sea-state	F_{TRP}
Beaufort-summer/fall	0.67	0.85	0.70	0.40
Beaufort-summer	1.00	0.85	0.70	0.60
Grand Banks-summer	0.71	0.65	0.55	0.25
Grand Banks-winter	0.38	0.92	0.13	0.05
Scotian Shelf-summer	0.67	0.81	0.58	0.31
Scotian Shelf - winter	0.42	0.95	0.17	0.07

5.3 Description of Scenarios and Evaluation of Response - Beaufort Sea

5.3.1 Beaufort Sea Subsea Blowout in Summer/Fall

Description of Scenario

A subsea blowout is assumed to have occurred in September at a well site located in 20 m of water. Oil is released at the sea bottom at a rate of 10,000 BOPD, accompanied by gas in the ratio of 135 m^3 of gas per m^3 of oil. The flow continues for 45 days until a relief well is successfully completed. The average air and water temperatures during the period are both 0°C. Wind speed averages 5 m/s (sea state 2 or 0.4 m significant wave height), and the surface current is 0.25 m/s.

In the boil zone where the gas is rising to the surface, the slick is about 200 m wide and 370 um thick. It is composed of fresh unemulsified oil with a viscosity of 25 cp. Within a kilometre's drift of the site, the slick has spread to about 740 m in width, it has lost 66% of its volume to evaporation and is an average of 34 um thick. With evaporation and wave action, emulsification has begun and about 31% water by volume has been incorporated. The viscosity has risen to 380 cp, and the pour point of the oil is -15° C.

After 19 hours, 95% of the original oil volume has been lost. The slick is 3440 m wide, about 803 m of which is covered by patches of emulsion with a viscosity of 17,000 cp. The total area of the slick is 20 km^2, of which 5 km^2 is thicker oil.

On day 30 after the event, 5/10ths grey-white ice moves over the site at a rate of 0.25 m/s, and this continues until the well is capped. The underside of the ice moving over the blowout site is painted with a strip of oil 200 m wide and 370

um thick. The water between the floes is covered by thinner oil. In total, over the 15-day period, 32.4 km^2 of ice floes are painted.

Best Practicable Response

Open water containment and recovery can be applied for the first 30 days, subject to environmental limitations. Assuming a 2-day delay in starting operations, F_{RT} = 28/30 = 0.93 and with prevailing environmental conditions, F_{TRP} = 0.60. Anywhere within 1 km of the well site, the entire slick can be captured by a boom swath of 750 m (F_{SI} = 1.0). Comparing the maximum recovery rate with the blowout rate and accounting for emulsified water (31%), evaporation and natural dispersion (66%):

blowout rate	=	10,000 BPOD
	=	66.25 m^3/h oil
weathered emulsion production rate	=	(1 - 0.66) (1 / (1 - 0.31)) (66.25 m^3/h)
	=	32.6 m^3/h fluid.

This is much less than the theoretical capacity of the skimming system (300 m^3/h); thus the skimmer efficiency factor F_{SE} = 1.0. For the last 15 days, open-water containment and recovery techniques cannot be applied.

Thus, the estimate of total oil fraction removed by the best practicable containment and recovery technologies is:

F = (28/30) (43/45) (0.40) (1.0) (1.0)
= 0.37 in the first 30 days
= 0.0 in the last 15 days.

For the oil that escapes the physical recovery operations in summer, chemical dispersion would be applicable. In this case, the total oil fraction removed would be:

$$F = F_{RT} \times F_{TRP} \times F_{AE} \times F_{DE}$$

In this scenario F_{RT} = 0.96, F_{TRP} = 0.85, F_{AE} = 1 and F_{DE} = 0.50.

Thus

$$F = 0.96 \times 0.85 \times 1 \times 0.50 = 0.41$$

In summary, (see Table 6), of the 300,000 barrels of oil discharged in the first 30 days of ice-free conditions, 66% or 198,000 barrels evaporate or naturally disperse while drifting one kilometre downcurrent from the blowout site. Of the remaining 102,000 barrels, 56% or 57,120 barrels can be physically recovered. Of the 44,880 barrels of oil escaping the physical recovery operation, 41% or 18,400 barrels can be chemically dispersed. In total, 76,480 barrels escape all operations. It will ultimately take about 19 hours for this oil to dissipate through further evaporation and dispersion.

During the remaining 15 days of fall, 150,000 barrels are discharged; 75,000 barrels are trapped under the ice where they remain fresh until spring and 75,000 barrels are discharged onto the water between floes, where 56% evaporates, leaving 33,000 barrels of weathered oil frozen in the surface of the new ice. During spring melt, 13,000 of the 75,000 barrels trapped beneath the ice can be burned in-situ using aerial ignition techniques and 42,000 barrels will evaporate. After break-up, 53,000 barrels of weathered oil (33,000 from the oil frozen in the surface of new ice and 20,000 remaining from oil painted under grey-white floes) will remain.

Response Based on Existing Capability

In the event of an uncontrollable subsea blowout a number of activities would be initiated concurrently but only those related directly to the operational response will be addressed at this time.

It is assumed that the drillship involved with the incident has successfully evacuated from the blowout site and is available immediately to begin drilling a relief well to eventually control and stop the flow. At least one additional floating drilling unit can also be brought in within about a week to drill a second relief well. Furthermore, given the water depth at the Amauligak site and assuming that the well lost control late in the drilling season, a bottom-founded drilling unit such as the SSDC, owned by Canmar, could be mobilized within 2 - 3 weeks and could be set down nearby to provide relief well capability. This would permit drilling to proceed as long as required into and indeed throughout the winter if necessary. The unit could also be positioned strategically relative to prevailing ocean currents to provide an effective barrier to ice as it begins to form later in the season. This barrier would create an open-water lead on the lee side of the vessel, thereby providing "open-water" conditions over the blowout site approximately 30-50% of the time.

The oil spill response systems presently available in the area that would be deployed immediately to the blowout site include the Response Barge System and Fireproof Boom System. Both systems are part of the Beaufort Sea Oil Spill Co-operative and could be mobilized to arrive at the Amauligak site in about 24 hours.

While these systems were being mobilized to the blowout site, tracking buoys would be deployed to determine prevailing currents and to monitor the movement of escaping oil.

Assuming the well was not on fire, a decision would need to be made regarding the desirability of igniting the well. Primary factors to be considered would revolve around safety issues and the generation of emulsions. If it was determined that emulsion generation would be minimal, the well would be ignited. This would result in the immediate combustion and enhanced evaporation of 35-65% of the hydrocarbons and would permit safe marine operations within 75-100 metres of the well site. On the other hand, if it appeared that large quantities of difficult-to-handle emulsion would be generated, the well would not be ignited, or it would be extinguished if already burning.

Within approximately 24 hours, the primary oil spill response system would be on-site and would be deployed. Either system could provide initial containment of the entire outflow during the normal sea state conditions which generally prevail 70% or more of the time.

Alternatively, the two systems could be deployed to provide primary containment and partial recovery at source, with the backup system being deployed downstream to provide secondary containment and additional recovery capacity for oil escaping the first system.

As indicated earlier, Amauligak crude is a very light but typical Beaufort Sea oil which is projected to result in losses through evaporation and dispersion of up to 66% of the hydrocarbon volume by the time escaping oil has drifted 1 km downstream.

The recovery/incineration capabilities of the two systems are:

a) Response Barge - 1000 BOPD (can be upgraded to 5000 BOPD). Recovered oil can be off-loaded into storage vessels or can be incinerated.

b) Fireproof Boom - 5000-15,000 BOPD in-situ combustion (dependent upon prevailing current speed).

These two systems in place and functioning at peak effectiveness should be able to contain and recover or incinerate most of the oil remaining and contained within the offshore booms (30-40%) during the time permitted by sea state conditions. During storms or in the presence of significant ice concentrations, containment and recovery efficiency would be reduced, likely to 0%.

Particularly during storms, the natural forces of the sea would promote further and more rapid degradation of the Amauligak crude. Ninety-five percent of the crude oil volume is projected to be lost through the forces of evaporation and degradation within the first 24 hours. Government approved dispersants could be applied if deemed to be necessary or beneficial in aiding natural dispersion.

With the formation of sea ice commencing in October, the continuing operation and efficiency of the primary open-water systems will be dependent upon the ability to keep ice away from the blowout site and the sea surface captured by each containment system. Assuming the SSDC is being employed to drill a relief well and has been strategically positioned relative to prevailing currents, the blowout site will continue to be in "open-water" for much of the fall season. At the same time, ice moving around the blowout site will create a natural ice barrier highly conducive to in-situ combustion techniques.

Given the nature of the oil and the effectiveness of available in-situ combustion techniques, it is therefore felt that throughout the open-water to fall ice formation period most of the remaining oil (30-40%) can be recovered and/or burned within approximately 1 km of the well site using available equipment.

Comparison of Best-Practicable and Existing Capabilities

Industry's existing capabilities compare favourably to the best-practicable capabilities. The major difference is that industry will rely on in-situ combustion of the oil contained by fireproof booms rather than on physical recovery techniques. The capacity of the existing physical recovery system is only 1000 barrels of oil per day which is insufficient to deal with the amount of weathered emulsion encountered (32.6 m^3/hr or about 5000 barrels per day). If there are failures with the in-situ combustion system or inefficiencies associated with the burning of the emulsion (31% water), the physical recovery back-up system may be insufficient to deal with the situation. High capacity systems could (and would) be accessed from government and Alaskan industry sources to deal with the possible shortfall. Currently, the Beaufort Sea Co-ops capabilities are being re-evaluated and recommendations to provide an extra margin of protection will be forthcoming.

The idea that the SSDC will create an open-water area on its lee side, hence enhancing spill combustion techniques, is interesting and should be researched thoroughly. It cannot be counted on, however, because the positioning of the SSDC will likely be based on well-control considerations, logistic support and ice conditions. The idea deserves further research and planning discussions.

5.3.2 Beaufort Sea Subsea Blowout in Winter

Description of Scenario

A subsea blowout is assumed to have occurred in December at a drill site in 20 m of water. The release rate is 10,000 BPOD (1590 m^3/day) with a gas-to-oil ratio of 135 m^3/m^3. It is assumed that the flow continues for 45 days until a relief well can be completed. The average temperature during the winter is -25° C, the average wind speed is 4.2 m/s, and the ice moves over the blowout at an average speed of 0.035 m/s.

The majority of the large oil droplets are painted on the underside of the ice in a strip about 200 m wide. The average thickness of oil under the ice is 2.6 mm. Smaller oil droplets accumulate in an area of lightly oiled ice adjacent to this strip. This lightly oiled area may be as much as ten times larger than the area of heavily oiled ice. The oil trapped under the ice is quickly encapsulated by the growing ice cover.

When spring melt begins, the oil released in December and January appears on the surface of melt pools. About 50% will have appeared by June 19 and 100% by June 30. Oil exposed on the ice surface in spring is initially fresh, having been preserved while frozen. As the oil collects in melt pools, it will form slicks about 1 cm thick, of which about 56% will eventually evaporate.

After breakup, the conditions are similar to those described in section 5.3.1 for the summer Amauligak blowout.

Best Practicable Response

The best practicable response to this spill would involve tracking the oiled ice through the winter and carrying out a burning operation when the oil surfaces in melt pools the following spring. S.L. Ross (1981) has carried out a comprehensive investigation of this type of operation. About 75% of the spilled oil will be on the surface during the time available for a burning operation. An analysis of likely surface pool sizes indicates that 75% of the surfaced oil is contained in pools 10 m^2 or greater. By concentrating on only these large pools, the logistical effort is reduced to a level that is deemed maximum achievable (S.L. Ross 1981). Finally, of the oil that is ignited, a burning efficiency of 90% can be achieved assuming an initial thickness of 1 cm and an extinguishing thickness of 1 mm.

Combining these factors, the estimated total fraction of oil removed is:

F = (100% surfaced) (75% ignited) (1 cm - 1mm/1cm)
= 0.68

Of the 450,000 barrels of oil discharged over the 45 days, 68% or 306,000 barrels are removed by in-situ combustion. Of the remaining 144,000 barrels, 80,640 (56%) would evaporate, leaving 63,360 barrels of weathered oil on the water after breakup. Although a large proportion of this would dissipate through natural dispersion, much would remain on the surface.

Response Based on Existing Capability

In reality this situation is highly unlikely to occur because floating drilling operations, which could cause a subsea blowout, have normally ceased by the end of October or early November. Nevertheless, this situation could arise if it were assumed that the one floating drilling unit which could be operating as late as December has a failure. More likely, the blowout would have occurred earlier in the season and extended into the winter period.

In either event, at the Amauligak site a bottom founded unit such as the SSDC could be mobilized to the site and strategically located "upstream" of the blowout site as discussed earlier. The later into the winter season the blowout occurred, the more difficult it would become to mobilize the SSDC. Nevertheless, based on past late season operational experience and the immediate availability of five Class 4 icebreakers, it is feasible to accomplish this operation throughout December.

Assuming the SSDC was employed (applicable to well sites in water depths of 25-75 feet) the unit would be used to drill a relief well and would provide the major winter offshore base for oil spill response operations. In addition, as previously discussed, the presence of the SSDC would create "open-water" conditions over the well site for significant periods of time (30-50%) thereby permitting the application of in-situ combustion techniques.

During times when the well site was covered over with moving ice, rising oil would "paint" the bottom of the ice and would rapidly become encapsulated for the duration of the winter. Under these circumstances, tracking buoys would be deployed to monitor the movement of oil-contaminated ice throughout the winter. In the spring, a major oil burning program would be mounted using aerially deployed igniters and the newly developed helitorch technique to incinerate effectively approximately 50% of the oil rising to the ice surface during the spring period. By the time breakup occurred, most of the oil would have either been burned by these techniques or would have evaporated and degraded through natural processes.

Comparison of Best-Practicable and Existing Capabilities

The industry approach coincides with the best-practicable capabilities that exist today. Although the ignition and burning of the hundreds and even thousands of oil pools that will form in spring will be a very complex operation logistically, industry will have several months of planning time over the winter to gear up for the operation. Whereas previous studies in the early 1980s indicated that there could be a serious problem in manufacturing sufficient mechanical igniters (Dome Igniter or Drew Igniter) for the operation, the recently-developed Helitorch ignition system does not share this problem, and is ideally suited for the task.

5.3.3 Beaufort Sea Above-Sea Blowout in Summer

Description of Scenario

A blowout is assumed to have occurred on a drilling island in mid-July. The flow rate is 10,000 BOPD, with a gas-to-oil ratio of 135 m^3/m^3. The gas exits the 10-cm diameter drill pipe at the rotary table at a velocity of about 320 m/s, shattering the oil into 180-um diameter droplets. These droplets are shot upward about 50 m by the jet of gas and carried downwind by the 5 m/s wind. Droplets start to rain down on the water about 140 m from the rig, and most of the droplets have fallen onto the water surface within 550 m. Concentrations of oil in the gas cloud have fallen below the lower flammability limit within 50 m of the rig.

Wind speed averages 5 m/s throughout the 45 days required to drill a relief well. Air temperature averages 7°C, and the water temperature averages 5°C. The surface current is 0.25 m/s.

One kilometre downdrift of the rig, the slick is 84 m wide and 0.73 mm thick. The oil has lost 35% of its original volume, mostly to rapid evaporation of fine droplets in the air, and the slick has a viscosity of 214 cp and a pour point of -16°C. Emulsification has just started with the oil incorporating 22% water by volume.

Within 38 hours, 95% of the slick has dispersed or evaporated. The slick is now about 4500 m wide and consists mostly of sheen 1 um thick. About 220 m of this width is made up of emulsion balls 68 um thick with a water content of 75% and a viscosity of 12,850 cp. The density of the emulsion (1003 kg/m^3) is such that it could sink in fresh water or be easily overwashed by waves. The total area of the slick at this time is about 77 km^2, of which about 4 km^2 is thick oil.

Best Practicable Response

The best practicable response is to employ a containment and recovery system deployed within a kilometre downdrift of the rig. A two-day delay in starting operations gives a response time factor of F_{RT} = 43/45 or 0.96, and the environmental conditions allow the fraction of time that recovery is possible to be F_{TRP} = 0.60.

Given the narrow slick width, complete containment can be achieved with about 300 m of boom and the fraction of slick intercepted will be 100% (F_{SI} = 1.0). Similarly, the blowout rate of 66.25 m^3/h coupled with the moderate emulsification rate allows the entire contained slick to be recovered effectively by one or two high-rate skimmers, resulting in a skimmer efficiency factor of F_{SE} = 1.0.
The estimate of total oil fraction removed is:

$$F = (0.96)\ (0.60)\ (1.0)\ (1.0)$$
$$= 0.58$$

In summary, of the 450,000 barrels discharged, 35% or 157,000 barrels evaporate initially. Of the remaining 292,500 barrels, 58% or 169,650 barrels can be physically recovered. As in the Beaufort Subsea summer scenario, of the remaining 123,350 barrels, 41% or 50,570 barrels can be chemically dispersed. Finally, of the remaining oil (72,780 barrels) a further 21% evaporate (15,280 barrels) leaving 57,500 barrels of weathered oil in the environment.

It is noted that if the drilling platform in the scenario is a gravel island or a bottom-founded facility, the decision to ignite the blowing well would lead to a complete consumption of the discharging oil by burning at source and the result would be virtually no oil pollution of the surrounding water.

Response Based on Existing Capability

In terms of existing Beaufort Sea operations, it should be noted that only two drilling platforms could be involved in this scenario. Both are bottom-founded steel units namely the Molikpak and the SSDC.

In the event that either well blew out, it would be possible to ignite the well, if this had not already occurred in the first instance. If the well were ignited, either intentionally or otherwise, essentially all and certainly greater than 95 percent of the escaping hydrocarbons would be consumed immediately. In the case of the Molikpak unit, a relief well would have to be drilled using available floating drilling units. The SSDC on the other hand has a very large, shipshape configuration (over 200 metres long at the working deck) which has actually been designed to accommodate the drilling of a relief well from the forward end of the platform in the event of the primary well blowing out and even catching fire. The SSDC is designed to permit the installation of a fire protection wall to ensure the safety of workers,

accommodation quarters and ongoing relief well drilling operations. Since the platform itself is a waterfilled, steel and concrete reinforced, super tanker hull, heat from the burning well would be dissipated rapidly thereby retaining the structural integrity of the platform itself. Alternatively, or in addition, relief wells could also be drilled using floating drilling units.

Assuming that a deliberate decision were made not to ignite the well, and most of the oil escaped from the platform and landed on the water, the oil spill response systems deployed would be the same as those described previously for the open-water scenario. Spill containment and recovery efficiencies would be similar and it would be anticipated that 30-40% of the oil could be recovered in close proximity to the well site during the open water period. Most of the remainder would have evaporated and/or dispersed through natural process in less than 48 hours.

Comparison of Best-Practicable and Existing Capability

This situation represents the ultimate countermeasure for an offshore oil-well blowout: ignition and burning of the blowing well so that virtually all oil is consumed at source and no on-water cleanup techniques are required. If the well is not ignited, the industry's present physical recovery capability may not be sufficient to deal with all the oil falling on water, as was the case for the first scenario. Although in-situ burning techniques are likely to succeed, improving the existing physical recovery capacity should be considered.

5.3.4 Beaufort Sea Above-Sea Blowout in Winter

Description of Scenario

A blowout is assumed to occur from a bottom-founded drilling caisson in December. The flow rate is 10,000 BOPD with a gas-to-oil ratio of 135 m^3/m^3. As in the summer scenario, the high gas exit velocity shatters the oil into small droplets that are carried over the deck of the caisson and the surrounding rubble field and fall onto the moving ice beyond. The explosion zone extends about 50 m downwind of the rig.

The oil falls on the ice (moving at 0.035 m/s) and forms a slick about 8.25 mm thick that saturates the 1 cm of hard-packed snow on the ice The average temperature is -25°C, and the average wind speed is 4.2 m/s. Twenty-four hour darkness prevails.

The swath of oiled snow is about 64 m wide. Approximately 16% of the oil evaporates initially, and the remainder has a viscosity of 60 cp. Even at the cold winter temperatures and mixed with snow, evaporation proceeds quickly until the oil pour point reaches -25°C and it gels.

Over the 45 days required to control the blowout, a total of 136 km of ice is oiled (total area = 27 km^2). About once every five days blowing snow covers the oil, hiding it from sight. By June 1, the snow has melted and heavily weathered oil spreads with the meltwater over an area twice that originally oiled (i.e., 54 km^2). Once the snow meltwater disappears, the oil collects in meltpools. The average slick thickness is about 1 cm.

Best Practicable Response

The best practicable response is to ignite and burn the oil on the ice while ensuring that the fire

does not spread back to the rig. This can be accomplished by shovelling oiled snow away from the rig to create a swath of clean ice about 10 m wide. Burning would be unfeasible only when the wind direction was opposite to the direction of ice drift . The predominant ice drift is to the west; and winds from the west occur about 20% of the time in winter, thus allowing the burning operation to proceed about 80% of the time. Blowing snow may limit operations one day in five, so burning could be conducted about 64% (0.8 x 0.8 x 100%) of the time with an estimated removal efficiency of 88% (1 - 1/8.25). In total, 72,000 barrels will evaporate before the oil hits the ice, and 212,000 of the 450,000 barrels discharged (47% = 64% x 88% x 100% - 16%) could be burned in situ near the site. Of the unburnt oil, 66,400 barrels (56% - 16%) will evaporate leaving 99,600 barrels of heavily weathered oil and burn residue on the ice during spring melt. It is assumed that this oil can still be ignited, and based on only those pools 10 m^2 or more in area, a further 68% (75% greater than 10 m^2 (1-1/10)) or 68,000 barrels can be burned in situ leaving 31,600 barrels of heavily weathered oil and burn residue on the water after breakup.

As for the previous above-sea Beaufort Sea blowout, it should be noted that if the incident occurs on a gravel island or a bottom-founded structure, a decision might be made to sacrifice the rig and ignite the well at source. This would deal with all the discharging oil and prevent any oil pollution of the surrounding water.

Response Based on Existing Capability

The same factors described for the previous scenario apply for the winter period. For either of the two drilling rigs which could face this situation, the well could be ignited and more than 95% of the oil burned immediately. The burning operation could last for the duration of the well blowout condition. It should be noted that although it is generally assumed that this could mean for the rest of the winter, in reality the blowing well would likely shut itself in through natural bridging processes within a few days to one month. The unconsolidated nature of the Beaufort Sea substrate sediments are particularly prone to this, and the worldwide record of natural bridging phenomena indicates that approximately 50% of all blowouts ceased naturally and more than 77% of all blowouts last less than 30 days (Gulf 1981).

In the event that the well was not ignited, the oil escaping from the blowing well-bore would eventually find its way to the sea ice surface where it would collect. Although a winter in-situ burning operation would be conducted, much of the oil would probably remain in place until spring when a major in-situ burning operation would be mounted. Since the oil available in the spring would be in a fresh, unemulsified form, a very high combustion efficiency (90-95%) would be anticipated. The remainder of the oil would evaporate and degrade naturally, with very little remaining to be dispersed by natural processes upon breakup of the sea ice.

Comparison of Best-Practicable and Existing Capabilities

This scenario demonstrates the best removal efficiencies of all crude oil blowout situations considered. If the well is ignited, virtually all oil is consumed in the fire and no oil is present on the ice or water surface. If the well is not ignited, all but 7% of the oil discharged can be removed through in-situ burning techniques.

5.4 Description of Scenarios and Response Evaluation - Grand Banks

5.4.1 Grand Banks Subsea Blowout in Summer

Description of Scenario

A subsea blowout is assumed to occur in mid-July on the Grand Banks in 80 m of water. The flowrate is 10,000 BOPD with a gas-to-oil ratio of 267 m^3/m^3. The average wind speed over the 45 days required to control the well is 7 m/s (sea state 3 or 1 m significant wave height). The surface current is 0.25 m/s. The average air temperature is 9°C and the average water temperature is 8°C. The width of the slick at the boil zone is about 800 m. At this point the oil is fresh and has a viscosity of 11 cp and a pour point of 6°C. One kilometre downdrift of the well site, the slick width has increased to about 2500 m and the slick has lost 25% of its original volume to evaporation and natural dispersion. It is now about 43 um thick and consists of a 50% water/oil emulsion with a viscosity of 50,000 cp and a pour point of 24°C, about 15C° above the ambient air and water temperature. The slick is comprised of viscous mats and balls of emulsion rather than a continuous slick (because the air temperature is below the pour point of the oil emulsion).

After about 30 hours, the density of the emulsion exceeds 1000 kg/m^3, and approaches that of seawater, and with the prevailing seas in the area, the emulsion balls and mats will be submerged in the upper metre of the water column most of the time.

Ninety-five percent of the original oil in the slick is expected to evaporate and disperse naturally within 32 days after release. By that time, most of the slick will consist of a 290-km wide swath of sheen with only about 1% of the width made up of very small balls of viscous gelled emulsion. (The total surface area covered by the sheen at this point will be very large, a small proportion of which will be covered by thicker oil.) The density of the emulsion will be 1023 kg/m^3, and it is very likely distributed throughout the upper 10 m of the water column.

Best Practicable Response

The best practicable response is to employ a containment and recovery system close to the blowout source. As described earlier, a two-day delay in starting operations gives a response time factor of F_{RT} = 43/45 or 0.96, and the environmental conditions allow the fraction of time that recovery is possible to be F_{TRP} = 0.25. Assuming that containment booms can be set up within about 500 m of the source, a rough estimate of slick width at that point is about 1650 m. Using the maximum feasible boom length of 2250 m gives a boom swath of 750 m and a slick interception factor of F_{SI} = 750/1650 or 0.45. Factoring the 25% evaporative and dispersive losses, the 50% emulsification, and the slick interception factor into the blowout rate of 66.25 m^3/h gives an emulsion encounter rate of:

$$\text{encounter rate} = (66.25\ m^3/h)\ (0.75)\ (1/0.50)\ (0.45)$$
$$= 45\ m^3/h$$

This is well within the recovery capabilities of at least two of the available high-rate skimmers, giving a skimmer efficiency factor of 1.0.

The estimated total oil fraction removed is:

$$F = (0.96)\ (0.25)\ (0.45)\ (1.0)$$
$$= 0.11$$

In summary, of the 450,000 barrels of oil discharged, 25% or 112,500 barrels are lost

initially through evaporation and natural dispersion. Of the remaining 337,500 barrels, 11% or 37,130 barrels can be physically recovered. The remaining 300,370 barrels will be comprised of viscous mats and balls and will persist for a long period on the surface. It will take more than one month for the oil to dissipate through further evaporation and natural dispersion. Fortunately, the oil has virtually no chance of contacting Canadian shorelines (S.L. Ross 1984), but the oil does represent an undetermined threat to seabirds in the area.

Description of Response Based on Existing Capability

ESRI has on hand in St. John's, 1000m of Vikoma Oceanpak boom and two Framo ACW-400 skimmers. ESRI maintains all equipment in good working order and has a core staff of highly trained people on call at all times. The ESRI team and equipment can be mobilized to the offshore site within 24 hours.

However, especially with the present low level of drilling activity on the eastcoast, it is unlikely that the supply boats needed to mount and operate the spill countermeasure equipment would be available right away: immediate effort (and logistic support) would be directed to well control and any search and rescue efforts. Thus, there would be a delay beyond the 48 hours in which ESRI could get to the site.

Even assuming that the ESRI team and equipment can be operating on site within 48 hours, the physical recovery of oil will likely be limited as the Framo ACW-400 skimmers cannot pick up oil or emulsions as viscous as the waxy crudes and the resulting emulsions from the Grand Banks.

Spill tracking operations would be initiated immediately and additional, pre-arranged sources of equipment and personnel, such as OSR Ltd., would be put on alert. The fishing industry would be briefed and baseline environmental data accessed for detailed field response planning. An environmental effects monitoring program would be initiated (using a research vessel).

Comparison of Best Practicable and Existing Capabilities

Physical recovery of oil with best practicable technology is calculated to be 11% or 37,130 barrels of the oil lost. With present ESRI equipment, physical recovery of waxy oil will be extremely limited primarily due to the inefficiency of the Framo ACW-400 skimmers with waxy crude. As well, more ocean boom would be needed to improve the response capability. Both additional boom and more effective skimmers are available through, for example, OSR Ltd. Natural processes, such as evaporation and dispersion, will be of greatest assistance in breaking up and eventually eliminating the spilled oil.

5.4.2 Grand Banks Subsea Blowout in Winter

A subsea blowout is assumed to occur in 80 m of water in January on the Grand Banks. The flowrate is 10,000 BOPD with a gas-to-oil ratio of 267 m^3/m^3. The average wind speed is 11 m/s (seas state 5 with 3 m significant wave height), air temperature is -2°C, and the average water temperature is 3°C. The surface current is 0.25 m/s.

At the boil zone, the slick is 800 m wide and 90 um thick composed of fresh oil at a temperature below its pour point (6°C). As such, the oil is in the form of gelled droplets with a diameter of about 450 um. It evaporates and disperses

naturally much more slowly than in summer, losing only 17 % of its volume by the time it drifts one kilometre from the site (just over one hour) and takes more than 8 weeks to lose 95% of its original volume. Because of its gelled form, the oil does not emulsify, but the viscosity of the oil increases from 3300 cp at one hour to 500,000 cp after eight weeks. In the heavy seas common in winter on the Grand Banks, it is likely that the droplets will be submerged in the upper few metres of the water much of the time.

Because the oil from this blowout survives so long at sea, it covers large areas. After 45 days (the time to control the well) the slick covers an area of 143,000 km^2 of which 2160 km^2 is thicker oil (i.e. droplets).

Best Practicable Response

The best practicable response is to employ a containment and recovery system close to the blowout source. An important assumption for effective recovery is that the oil is present on or very near the surface in moderate seas and is thus available for skimming. As described earlier, a two-day delay in starting operations gives a response time factor of F_{RT} = 43/45 = 0.96, and the environmental conditions allow the fraction of time that recovery is possible to be F_{TRP} = 0.045. At 500 m from the blowout source, the slick is about 1650 m wide. Assuming that containment booms can be set out at that point, using the maximum feasible boom length of 2250 m gives a boom swath of 750 m, and a slick interception factor of F_{SI} = 750/1650 or 0.45. Factoring the 17% evaporative and dispersive losses and the slick interception factor into the blowout rate of 66.25 m^3/h gives and oil encounter rate of:

oil encounter rate
= (66.25 m^3/h) (0.83) (0.45)
= 25.0 m^3/h

This is well within the recovery capability of one of the specified high-rate skimmers, giving a skimmer efficiency factor of 1.0.

The estimated total oil fraction recovered is:

F = (0.96) (0.045) (0.45)
= 0.019

In summary, of the 450,000 barrels discharged, 17% or 76,500 barrels evaporates and disperses initially. Of the remaining oil, only 1.9% or 7,100 barrels can be physically recovered. The remaining oil (366,400 barrels) is in the form of highly viscous droplets and persists on the ocean surface for months, only slowly evaporating and dispersing.

Description of Response Based on Existing Capability

Unlike the summer scenario where emulsion formation produced a highly viscous product (50,000 cp), the spill in winter creates a gelled oil product that has a viscosity of only 3300 cp measured at a location 1 km downcurrent from the blowout. At this oil viscosity, the ESRI skimming system has a recovery capacity of about 40 m^3/hr, which is more than sufficient to handle the encounter rate of 11 m^3/hr (66.25 x 0.83 x 0.20). This means the skimmer efficiency factor is equal to 1.0. Physical recovery of about 1% of the spilled oil can be achieved.

Spill tracking operations would be initiated immediately and additional, pre-arranged sources of equipment and personnel, such as OSR Ltd., would be put on alert. The fishing industry would be briefed and baseline environmental data accessed for detailed field response planning. An environmental effects monitoring program would be initiated.

Comparison of Best Practicable and Existing Capabilities

Under winter conditions, the spilled oil that doesn't evaporate forms gelled droplets which gradually increase in viscosity. With more ocean boom available, the present ESRI skimmers can recover as much oil as using best practicable technology. However, since physical recovery of only 2% of the oil appears possible, the alternative of no equipment response should be considered.

5.4.3 Grand Banks Above-Sea Blowout in Summer

A blowout is assumed to occur on a floating drilling platform on the Grand Banks in mid-July. The flowrate is 10,000 BOPD with a gas-to-oil ratio of 267 m^3/m^3. The gas exits the 10-cm diameter drill pipe at a velocity of about 520 m/s (sonic velocity) and shears the oil into a mist of droplets with an average diameter of 75 um and shoots them 50 m into the air. The average wind speed is 7 m/s (sea state 3 or 1 m significant wave height). Average air and water temperatures are 9°C and 8°C, respectively. The surface current is 0.25 m/s.

The oil droplets settle on the water surface in a slick about 110 um thick, consisting of gelled droplets of 50% evaporated oil with a viscosity of 83,000 cp and pour point of 41°C. Since the small oil droplets evaporate sufficiently in their travel through the air to raise the oil's pour point above ambient temperature, they do not form a slick on the water surface, but remain as discrete droplets. It is likely that the droplets will be submerged in the upper metre of the water column much of the time, rather than floating on the surface because of the high density of the evaporated oil (initially 960 kg/m^3), the small droplet size and the prevailing sea states.

It is expected to take almost 37 days (880 hours) for 95% of the original oil to be evaporated and naturally dispersed. At this point, the slick covers an area of about 200,000 km^2 of which 910 km^2 is made up of small droplets of gelled oil.

Best Practicable Response

The best practicable response is to employ a containment and recovery system just down-drift of the droplet fallout zone. The effectiveness of this operation is highly questionable, depending greatly on whether the oil is present on or very near the sea surface and available for skimming. The proposed operation may be effective if one can assume the moderate seas that allow skimming will also allow the oil to be present on the sea surface.

As described earlier, a two-day delay in starting operations gives a response time factor of F_{RT} = 43/45 or 0.96 and the environmental conditions allow the time that recovery is possible to be FT_{RP} = 0.25.

The width of the slick at the downstream edge of the droplet fallout zone is about 670 m, within the maximum boom swath of 750 m. The slick interception factor is F_{SI} = 1.0. Factoring the estimated 50% evaporation into the blowout rate of 66.25 m^3/h gives an oil encounter rate of 33.1 m^3/h, well within the capability of one high-rate skimmer. The skimmer efficiency factor is thus 1.0.

The estimated total oil fraction recovered depends only on response time and environmental conditions.

$$F = (0.96)\ (0.25)\ (1.0)\ (1.0)$$
$$= 0.24$$

In summary, of the 450,000 barrels discharged, 50% or 225,000 barrels evaporate initially. Of the remaining 225,000 barrels, 24% or 54,000 barrels can be physically recovered if it is assumed that the oil (in the form of gelled droplets) is available for skimming on the surface. The remaining 171,000 barrels will persist for several weeks before dissipation through slow evaporation and natural dispersion.

Description of Response Based on Existing Capability

As with the case of summer sub-sea blowout, the viscosity of the oil (83,000 cp) is beyond the capability of ESRI's Framo ACW-400 skimmers and little physical recovery can be expected.

Spill tracking operations would be initiated immediately and additional, pre-arranged sources of equipment and personnel, such as OSR Ltd., would be put on alert. The fishing industry would be briefed and baseline environmental data accessed for detailed field response planning. An environmental effects monitoring program would be initiated.

Comparison of Best Practicable and Existing Capabilities

Under these conditions, the present ESRI equipment does not have the capability to physically recover spilled oil. However, with the best practicable technology (different skimmers and more boom), it may be possible to pick up as much as 24% of the oil from the blowout. Such equipment is available through other response groups.

5.4.4 Grand Banks Above-Sea Blowout in Winter

Description

A blowout from a platform is assumed to occur in January on the Grand Banks. The flowrate is 10,000 BOPD (66.25 m^3/h) with a gas-to-oil ratio of 267 m^3/m^3. The high exit velocity (sonic) of the gas shatters the oil into a mist of droplets averaging 75 um in diameter. The average wind speed is 11 m/s (sea state 5 or 3 m significant wave height), the air temperature averages -2°C and the average water temperatures is 3°C. The surface current is 0.25 m/s.

By the time the oil hits the water surface, the wind has spread the cloud of droplets out to cover a width of about 800 m. Average thickness on the surface is 93 um. The oil has lost 44% of its original volume through evaporation by the time it hits the water, and the droplets do not coalesce to form a slick. Evaporation has raised the pour point of the oil to 30°C, its viscosity is 137,000 cp and its density is 950 kg/m^3. Because of the high density of the oil and high seas prevalent in the area in winter, the oil droplets do not float on the surface but are mixed in the upper few metres of the water column.

It will take the oil about 8 weeks to lose 95% of its volume to evaporation. After 45 days, the oil would cover an area of 270,000 km^2 of which 780 km^2 is covered by more concentrated droplets.

Best Practicable Response

The best practicable response is to employ a containment and recovery system just downdrift of the droplet fallout zone. The effectiveness of

this operation is highly questionable, and success depends on the oil being present on or very near the water surface and thus available for skimming. If one can assume that the moderate seas that allow skimming will also allow the oil to be present on the sea surface, then the proposed operation may be effective.

A two-day delay in starting operations gives a response time factor of F_{RT} = 43/45 = 0.96, and the environmental conditions allow recovery operations to proceed only 4.5% of the time (F_{TRP} = 0.045). The width of the slick at the downstream edge of the droplet fallout zone is about 800 m, marginally greater than the maximum boom swath of 750 m. The slick interception factor is F_{SI} = 750/800 = 0.94. Factoring the estimated 44% evaporation into the blowout rate of 66.25 m^3/h gives an oil encounter rate of 37.1 m^3/h, well within the capacity of one high-rate skimmer, so the skimmer efficiency factor (F_{SI}) is 1.0.

The estimated total oil fraction removed depends mainly on the response time and the environmental conditions.

F = (0.96) (0.045) (0.94) (1.0)
= 0.04

In summary, of the 450,000 barrels discharged, 44% or 198,000 barrels are lost initially through evaporation. Of the remaining 252,000 barrels, only 4% or 10,080 barrels can be physically recovered. The remaining 241,920 barrels of oil in the form of gelled balls of viscous oil will persist for weeks and even months and cover large areas of ocean.

Response Based on Existing Capability

With the high seas and winds during the winter months, countermeasures equipment is largely ineffective. In addition, the highly viscous nature of the waxy crude makes physical recovery of spilled oil difficult to impossible. Therefore, initially zero recovery is expected.

Spill tracking operations would be initiated immediately and additional, pre-arranged sources of equipment and personnel would be put on alert. The fishing industry would be briefed and baseline environmental data accessed for detailed field response planning. An environmental effects monitoring program would be initiated.

Comparison of Best Practicable and Existing Capabilities

As with a subsea blowout in winter, physical recovery of spilled oil is minimal even with best practicable technology i.e. about 4% compared to existing ESRI capability of near 0%.

5.5 Scotia Shelf Blowout Scenarios

5.5.1 Scotia Offshore Subsea Blowout - Summer and Winter

Description

A subsea blowout is assumed to occur at a drill site near Sable Island. The flowrate is 1000 BOPD of condensate with a gas-to-oil ratio of 17,000 m^3/m^3. The average wind speed is 7 m/s (sea state 3 or 2 m significant wave height), the air and water temperatures average 15°C, and the surface current is 0.38 m/s.

At the boil zone, the slick is 1155 m wide and 4 um thick. Because the condensate is so volatile and dispersible, it is not expected to survive for more than 1 km downdrift.

In a similar situation in winter, increased average winds of 11 m/s and heightened sea states (sea state 5 or 3 m significant wave height) would disperse the condensate even more quickly.

Best Practicable Response

Considering the very short survival times of the slick, no countermeasures are warranted other than surveillance and monitoring.

5.5.2 Scotia Offshore Above-Sea Blowout - Summer and Winter

Description

A platform blowout is assumed to occur on a rig near Sable Island. The flowrate is 1000 BOPD of condensate with a gas-to-oil ratio of 17,000 m^3/m^3. The average wind speed is 7 m/s (sea state 3 or 1 m significant wave height), air and water temperatures are 15 °C, and the surface current is 0.38 m/s.

The gas exits the 10-cm diameter drill pipe at sonic velocity (520 m/s) atomizing the condensate to a fine mist with an average droplet diameter of 2 um. If all the mist were to fall on the water surface, it would form a slick about 980 m wide and 5 um thick. However, most of the condensate evaporates before it hits the water and what little does fall disperses naturally since it is less than 1 um thick.

In winter with higher wind speeds and heightened sea states, the slick would be even smaller and would disperse more quickly than in summer.

Best Practicable Response

Considering the very short survival times of the slick, no countermeasures are warranted other than surveillance and monitoring.

6.0 INDUSTRY'S OVERALL OIL SPILL RESPONSE CAPABILITY

6.1 Elements Of A Major Oil Spill Response Effort

Response to a very large oil spill requires the successful bringing together and coordination of a number of key elements, of which cleanup equipment is but one. The purpose of this section is to evaluate industry's existing capability with respect to these other important response components. Most of the components, such as communication systems, training programs, and spill tracking systems, are not strongly dependent on spill type and behaviour, so their analysis can avoid the use of spill scenarios. There are certain differences in response capability between the Beaufort Sea and Grand Banks situations, so each region is considered separately where major differences exist.

Response capability for major spills can be evaluated by analyzing the plans, people and technologies involved. An effective capability must include organizational structures and contingency plans that are well designed and thoroughly exercised; response personnel who are highly knowledgeable and thoroughly trained; and equipment and technologies that can do the intended job in the most effective manner possible.

Within these three divisions are specific components that together contribute to the total response capability. These include:

Preparedness and Plan

* Contingency Plans
* Communication Plans
* Government Approvals
* Public Information Plans

Response Tools

* Cleanup Equipment
* Logistical Systems
* Spill Tracking Systems
* Spill Modelling
* Sensitivity Mapping

Response Personnel

* Skilled Manpower
* Training and Exercise Programs

6.2 Response Structures and Plans

6.2.1 Contingency Plans

Oil spill contingency plans are one of the most essential components of an effective oil spill response. Their purpose is to describe the actions that need to be taken to respond rapidly and effectively to oil spills. To be effective, contingency plans must be clear, concise, "user friendly", up-to-date and realistic. Contingency plans outline the response organization, lines of authority and responsibility, and channels of communication to be employed. They serve to identify the key response members, define the duties and responsibilities of each member, and outline the many decisions that may have to be made and by whom. Contingency plans also identify the equipment and resources required and available to deal with spills and the main strategies to be employed for different sets of circumstances and conditions.

For each offshore area, the active operators are required by COGLA and the applicable Regional Offshore Petroleum Board to have in place up-to-date oil spill contingency plans to deal with any oil spill incident which may arise during the course of operations. Prior to receiving approval for any plan, they are reviewed by each of the appropriate regulatory and resource agencies, including the Federal Departments of Fisheries and Oceans, Environment, Transport (Coast Guard) and Energy Mines and Resources. Beaufort Sea plans are also reviewed by the Department of Indian and Northern Affairs.

As well, with the advent of the Joint Environmental Screening Committee, established under the Inuvialuit Final Agreement, draft plans are now also distributed to this committee, thereby introducing inputs from the Inuvialuit people and their technical experts.

In general, industry operators in the Beaufort Sea and on the East Coast believe that their contingency plans are adequate. However, two possible concerns have been identified. The first relates to the recognition that no major spill contingency plan can be properly evaluated simply by "paper" reviews. The ultimate test (aside from an actual spill) is to use the plan in a simulated response exercise involving all senior executives, managers, superintendents and supervisors identified in the plan. Such exercises are expensive and time-consuming but are felt to be the only reliable test of the adequacy of a plan (the exercise also serves as a training opportunity).

The other concern identified is that existing contingency plans, although adequately describing actions, responsibilities and resources associated with the initial phases of a major spill, do not generally follow through to define the longer term response requirements. This is an important factor when considering the Exxon

Valdez spill: although the initial response involved only locally available equipment and personnel, the longer term response involved hundreds of pieces of equipment from all parts of the worlds, scores of outside experts and specialists, and thousands of workers. A similar situation might occur for a spill offshore Canada especially if shoreline contamination was anticipated. This should be planned for to the fullest extent possible.

6.2.2 Communication Plans

The effective flow of communications during a major spill is of critical importance to a successful response effort. The general topic of communications is broad ranging, but is limited herein to inter/intra company communications and communications between companies and the government.

A major strength of the offshore oil and gas industry is the communication of technical and management information between onshore and offshore facilities and between field and headquarters operations. Clear lines of communication have been established and are described in the oil spill contingency plans of the respective offshore operators. These communication links are tested on an annual basis through telephone/radio/paper exercises.

It is a requirement of these plans that all oil spills larger than two barrels are reported immediately to the 24-hour Federal Government Spill Line and to the COGLA regional office. These initial messages trigger further rounds of communication in ever widening circles, depending on the nature and gravity of the incident.

In addition, there will be the need to carry out effective communications on an ongoing and increasing basis in the field as an emergency response to an oil spill incident develops. The industry emergency communications centres are presently set up to communicate directly with all company-controlled aircraft, vessels and work sites.

In the event of a very large sustained oil, spill the communications network would need to expand to include all aircraft, vessels and response cleanup teams working in the area. Communication links would have to be developed with various government departments regarding the establishment of aircraft and vessel exclusion and safety zones, the streamlining of customs procedures for the delivery of foreign equipment and materials, and other government responsibilities that impinge on spill emergency operations. These and other communications requirements are not fully identified in existing industry plans.

6.2.3 Government Approvals

In the event of a major offshore oil spill incident, all decisions, including those that involve the regulatory agencies, must be made in a timely and effective fashion. Recent events related to the Valdez spill have highlighted the importance of making the right decisions at the right times for the right reasons.

An oil spill response in the Canadian Beaufort Sea will rely heavily on the application of techniques and countermeasures such as well ignition, in-situ and onshore incineration of oil, the application of dispersants, and the protection of prioritized sensitive shoreline areas. These strategies have been described and incorporated as essential features of the industry's government-approved oil spill contingency plans.

However, there is presently no assurance that government decisions on issues involving environmental trade-offs will be made quickly during an emergency situation. For example, although the government and the industry have jointly developed (through the Environmental Studies Research Fund (ESRF)) a dispersant-use decision- making system for the Beaufort Sea that allows decisions to be made within minutes or a few hours, the system has not been tested on a simulated basis, nor have industry environmental advisers and government decision-makers been trained on the system.

The development of pre-spill approvals for dispersant use and in-situ burning of oil spills and disposal of oiled debris through incineration and landfilling would enhance industry's ability to carry out an effective response effort. Where prior approvals are not possible or appropriate, as a minimum, clear descriptions of the decision-making methodologies that will be used during the spill event are required and assurances should be given that decisions will be made on a timely basis.

6.2.4 Public Information Plans

A very large oil spill extended over weeks or months in Canadian offshore waters would receive great local, national, and international attention. The media would expect full co-operation in reporting the spill on a regular basis, interviews with personnel directly involved with spill response operations, and also access to company executives at the highest level. In addition to pressure from the media, the company involved would be besieged by oil spill equipment manufacturers, consultants, special interest groups, volunteers and salesmen who will offer instant solutions or demand immediate attention. Although existing company contingency plans identify positions responsible for public relations, current plans and training may not be adequate to deal with the requirements of a very large, sustained oil spill in the offshore environment. There is a need for prearranged policies and programs to deal with volunteers and special interest groups, structures for the screening of telephone enquiries and sales representatives, systems for providing media interviews and briefings and for monitoring media reports and providing feedback to the spill managers, and mechanisms to ensure coordination, as required, with government representatives.

6.3 Response Tools

6.3.1 Cleanup Equipment

The following summarizes the present situation for the two main offshore areas where spill cleanup equipment is required.

Beaufort Sea

Based on this evaluation, it is believed that the oil spill equipment currently in place in the Beaufort Sea, although not all state-of-the-art, is generally adequate and sufficient to deal with a very large blowout spill, within existing environmental and technological constraints. Although immediately available skimmers are of relatively low capacity, larger units with their operators could be accessed rapidly from government and other industry organizations.

The Beaufort Sea operators have available a number of major stockpiles of equipment including the Beaufort Sea Oil Spill co-op equipment, the Amoco/Canmar inventory at the Canmar Tuk Base Camp and at McKinley Bay, and the equipment available on board the various industry drilling platforms. In addition, the

Beaufort operators can access directly the Canadian Coast Guard equipment cache located at Tuktoyaktuk as well as CCG equipment which can be brought in from other Coast Guard depots in other parts of the country. The Canadian operators can also access the oil spill response equipment maintained by Alaska Clean Seas at Deadhorse, Anchorage and Dutch Harbor, Alaska.

The equipment readily available from these sources includes a number of state-of-the-art offshore recovery and treatment systems, containment barriers and booms, skimmer, pumps, burners, incinerators, oil storage bladders, sorbents, dispersants, portable camps and small watercraft.

In terms of testing and exercising the existing response equipment, at least one major oil spill response exercise is carried out each year in conjunction with the active operators and the Canadian Coast Guard. The joint exercise undertaken in late August 1989 involved a number of offshore vessels and included boom and skimmer deployments and a demonstration of the helitorch ignition system. In addition to the annual major exercise, the Beaufort Sea co-op conducts specific equipment exercises on a weekly basis throughout the operating season to test the equipment and to ensure personnel familiarity with equipment operations and limitations.

In the spring of 1989, prior to the commencement of the year's open water drilling program, the co-op was contacted and became actively involved in supplying equipment and personnel to assist with the Valdez incident. Within two days of receiving the orders the co-op had dispatched four Hercules aircraft loads of equipment, along with a small team of co-op personnel to Alaska. This equipment included 2250 feet of 36-inch boom, 250 feet of fireproof boom, 2000 aerial igniters, 1 helitorch, 2 saacke burners and a number of oil-storage bladders.

This rapid and effective response, mounted during the pre-season and with due regard for customs and regulatory considerations, demonstrated clearly the effectiveness of the co-op in responding rapidly to an emergency situation.

Despite the belief that the stockpile of equipment held by the Beaufort Sea Oil Spill co-op is generally adequate, an enhanced capability would be realized by the acquisition of at least one state-of-the-art high volume weir-type skimmer to replace the present VEP skimmer on the Oil Spill Response Barge and the purchase of additional fireproof boom to increase the present inventory of 250 feet to 500 feet.

Grand Banks

Due to the nature of the Grand Banks oils and the generally difficult sea states, the existing offshore skimmers owned by the east coast industry would be ineffective on Grand Banks blowout spills because they cannot handle high viscosity oils.

The limited immediate oil spill recovery capability presents a dilemma to the East Coast oil and gas industry and its spill response co-op, East Coast Spill Response Inc. (ESRI). ESRI developed its current inventory of oil spill equipment, which is known to function satisfactorily for normal oils (the large pieces of equipment are identical to the offshore equipment operated by the Canadian Coast Guard), before the serious recovery problems associated with Grand Banks waxy oils were known. ESRI became concerned after detailed ESRF studies in 1986 showed that these oils would produce unconventional and highly viscous spill products. During the summer of

1988, a joint CPA and Canadian Coast Guard (CCG) large-scale evaluation of various skimmer equipment on waxy crude, Bunker C and light oil confirmed that ESRI's (and CCG's) main offshore recovery device, the FRAMO ACW-400 skimmer, was ineffective on weathered and emulsified waxy crude oils.

In view of the existing situation, an ESRI-member company experiencing a major sustained blowout today would be forced to seek effective equipment and support from other oil spill co-operatives in the world. This support is expected to bring levels to or near the best practicable level of response that can be achieved. This response, due to the time required for appropriate support vessels to transit the Atlantic Ocean, would not be expected to be attained for two weeks after the spill occurs.

The East Coast industry through ESRI should be encouraged to complete its ongoing evaluation of its capability to provide the first-line response to a blowout spill. A possible outcome would be the upgrading of equipment for immediate deployment, while arranging for accelerated access to additional support vessels and recovery equipment. A feasible objective for mobilization of additional skimmers by air to St. John's would be three days. Allowing an additional day to transport these skimmers from St. John's to the spill site, this would produce a response which reaches the best practicable maximum within four days (as opposed to two days under the optimum scenarios presented).

6.3.2 Logistics

Logistics is the backbone of a major oil spill response operation. It involves the procurement, maintenance and transportation of required materials, equipment, personnel and facilities.

Key items include:

Vessels	Work Space
Helicopters	Receiving Facilites
Fixed Wing	Staging Areas
Trucking	Office Space
Tankage	Security
Warehousing	Safety
Wharf Space	Fuel
Accommodation	Personnel Processing
Personnel Records & Payroll	
Purchasing	

Companies operating in the offshore oil and gas areas are expert in matters of logistics, and company employees whose normal jobs involve the above responsibilities would perform the same jobs in an oil spill response operation and would do so effectively with little requirement for oil spill training.

The major logistical problem in oil spill response involves the ready availability of vessels, aircraft and accommodation to support cleanup equipment and operations, and these are the focus for the following discussion.

Beaufort Sea

The main logistics platforms needed to mount an offshore response to an oil spill are identified and updated annually in the oil industry contingency plans. In the Beaufort Sea region, a large number of vessels are operational and manned during the open water drilling season. They include vessels of the Canmar and Beaudril fleets, as well as a number of supply boats, workboats and tugs operated by northern seismic service companies, the Canadian Coast Guard and smaller contract vessels.

For nearshore shallow water work, there are a number of sea-truck and whaler-type oil spill

response vessels, as well as numerous aluminum boats and zodiacs belonging to the industry, government and private individuals. Most of these could be brought in to assist with an overall response as required on short notice.
In the event of a major offshore oil spill incident, it would be the intention of the industry operator to locate as soon as possible a substantial offshore support base in the immediate vicinity of the flowing well site. Several workbarges, each capable of providing accommodation for 100 to 200 people, shops, aviation fuel, helidecks, cranes, etc., are available for this purpose.

For offshore oil storage purposes, a number of very large ocean- going barges with considerable oil storage capacity are located in Tuktoyaktuk Harbour along with many smaller fuel barges. These vessels could be pressed into service if and as required.

Fixed wing and rotary aircraft available in the Beaufort Sea area have also been identified in the industry oil spill contingency plans. Although a number are immediately available, the local inventory would be quickly reinforced by more aircraft from other geographic areas. The Beaufort Sea coastline is fortunately blessed with a number of DEW-line airstrips located at various strategic locations along the Beaufort Sea Coast. Some of these are capable of handling large aircraft, which is clearly an asset for offloading oil spill response and shoreline clean-up/construction type equipment. In addition, MOT airports are located at Tuktoyaktuk and Inuvik.

Shore-based accommodations would be provided by the existing industry support bases located at Tuktoyaktuk along with several camps operated by non-oil industry contractors. Additional accommodations could be provided on a number of the offshore vessels presently not in use, if required.

A typical open water offshore response requirement, based on experience with previous worldwide offshore incidents, would likely involve approximately 200 to 300 personnel. It is felt that this number of people could be managed quite effectively in short order, with the available facilities.

East Coast

On the Canadian east coast logistical support to combat an oil spill from an exploratory wellsite would only be required for the Grand Banks. This is because oil discovered to date on the Scotian Shelf is very light and will virtually evaporate within a day. Also the discoveries are far offshore and spills may impact one shoreline, Sable Island. On the Grand Banks all discoveries have been made far offshore and the likelihood of contaminating east coast shorelines is virtually nil.

Sustained oil spill response on the Grand Banks will depend exclusively on large ocean going marine vessels (such as supply boats, tugs, coastal tankers) to position oil spill booms, skimming equipment and for oil storage. When multiple exploratory drilling operations are underway sufficient supply vessels would be available to launch oil spill response equipment quickly and effectively. When single drilling operations take place the availability of suitable vessels may be limited in the initial stages of a sustained blowout.

Accommodations for the manpower combatting an offshore spill will exist on the vessels themselves. Helicopters will be available from the drilling operation, its back-up support and CCG if necessary to transfer necessary equipment and manpower to sustain the spill response. As well, ocean going vessels (ie. fishing trawlers) can carry out these same functions. If the blowout continues these same vessels could be used to

conduct environmental effects studies of the oil and its impacts on the marine biota and commercial species.

Fixed-winged aircraft are used during drilling operations to survey for icebergs and sea-ice. During the initial phase of a spill these aircraft would track the oil movements and monitor fishing vessels to help them avoid a spill. Additional long range aircraft can be brought to Newfoundland from other east coast centres to provide platforms for wildlife monitoring surveys and for conducting electronic surveillance of the movement and characteristics of the spill as it disperses. Sufficient aircraft exist to undertake almost continuous oil spill monitoring.

6.4 Spill Tracking Systems

Detection and tracking of an oil slick is an essential operation for mounting an effective response to an oil spill. Because escaping oil can cover a large area rapidly, a combination of radio-tracking buoys and aircraft surveillance is necessary to monitor the movement and fate of an oil slick.

Direct visual observations from aircraft and ships would be made during all phases of a major spill control operation to determine the extent and movement of the slick. Should poor visibility exist or the spill cover a large area, radio-tracking buoys would be dropped in the slick to track its drift. The position of the buoys can be monitored from land, sea or air, using radio receivers. Both the Beaufort Sea co-op and ESRI maintain a stockpile of these buoys.

In the Beaufort Sea the tracking of oil-contaminated ice is an important counter-measures step. Satellite-tracked positioning buoys have been deployed successfully on Arctic ice to study its movement. In moving ice, the use of these buoys would permit the accurate positioning of oiled ice.

In addition to the tracking of oil movements with buoys, a number of airborne technologies are presently available for detecting oil on water, ice or snow. Esso Resources in Calgary and several Canadian service companies operate remote sensing equipment utilizing ultraviolet and infrared wavelengths to detect oil on the surface in darkness and under poor visibility conditions. These technologies have been employed successfully in actual field situations in the offshore Beaufort Sea, and most recently in conjunction with the Valdez spill.

The technologies remain limited in their ability to quantify the nature and amounts of oil remaining on the water/ice surface with time, to detect oil in and under ice, and to detect submerged particles and globules of oil formed during spills involving waxy crude oils, such as those from the Grand Banks wells.

6.5 Spill Trajectory Models

Computer spill simulation models exist for predicting the behaviour of offshore oil spills and predicting their movement as a function of local winds and currents. These models are used as a planning tool and as a real-time method of forecasting the location and characteristics of oil slicks. They can be used to describe the initial dimensions and characteristics of an offshore spill at source (as a function of oil type, spill type and size, and environmental conditions) and can then describe the likely behaviour of the oil in terms of the spill's persistence, dimensions and physical properties as a function of exposure to the environment.

Sophisticated spill trajectory models are available for both the Grand Banks and Beaufort Sea regions. They would be used to predict the expected trajectory, the speed of the slick's movement, and the location and timing of possible shoreline contact. As noted earlier, the industry's trajectory model for the Grand Banks area has been used to conduct an extensive analysis of the likely movement of spills from the Hibernia field. Using monthly weather records over the past twenty years, it has been shown that there is very little possibility of oil coming ashore.

The spill behaviour and trajectory models used by industry for Grand Banks and Beaufort Sea spills are considered state-of-the-art and will be used in the event of a major offshore spill.

6.6 Environmental Sensitivity Mapping

Environmental sensitivity mapping serves to provide the basic environmental information required for the effective planning and implementation of oil spill countermeasures in both coastal and offshore areas. In particular, sensitivity maps provide guidance in identifying areas that should be given priority in shoreline protection efforts. Information on environmental trade-offs associated with the use of dispersants, when used in conjunction with spill trajectory models, provide indications of potential environmental damage associated with the spill.

Beaufort Sea

In the mid-1970s, the then Arctic Petroleum Operators Association (APOA) funded a four-year study to map and incorporate all relevant environmental and shoreline countermeasures information into a manual. This manual, dated 1979 and entitled "Shoreline Oil Spill Protection and Clean-Up Strategies: Southern Beaufort Sea", was followed in 1980-81 by a major aerial mapping program of the entire Canadian Beaufort Sea from Demarcation Point to Prince of Wales Strait. The results were presented in the form of a series of videotapes. These tapes provide continuous and complete coverage of the shore zone along with technical advice and instructions on the nature and sensitivity of the shore zone, areas requiring priority protection, and the strategies to be employed to protect these sites and to mount an effective nearshore oil spill countermeasures response. Tape sets are presently available from and are maintained at the Canmar Base Camp in Tuktoyaktuk and the offices of Amoco Canada in Calgary.

More recently, Environment Canada (1987) published a new "Environmental Atlas for Beaufort Sea Oil Spill Response", which incorporates all of the previously available information plus new data and resource information relevant to the task of mounting a practical and effective response to oil spills in the Beaufort Sea coastal area on a year-round basis. The atlas is useful in three major areas: first to assist in the development of the most effective contingency plans for a specific area, second to provide a source document on which to base realistic oil spill training exercises, and third to act as a basic field reference for important environmental factors in an actual spill situation.

Finally, in 1988 the Environmental Studies Research Funds (ESRF) program published a "Guide to Dispersant-Use Decision Making for Oil Spills in the Canadian Southern Beaufort Sea". Aside from its main use as a dispersant-use aid, the document provides detailed sensitivity maps for 24 key offshore biological resources in the area including fish, waterfowl and marine mammals. When used in conjunction with the industry's spill trajectory and behaviour models,

the document allow one to predict the potential impacts of a given spill if treated with dispersants of if left untreated.

Given the availability of the above environmental sensitivity mapping efforts, oil spill response teams are well positioned to make the best possible decision and to plan for the most effective offshore and shoreline response strategies. It is recognized, however, that at the time of an oil spill the information contained in these documents would be supplemented by local knowledge and real-time data to verify or update the information available in the documents.

East Coast

On the Canadian east coast, environmental sensitivity mapping of many shoreline and offshore sectors of the region was undertaken between five and ten years ago by various petroleum companies. Shoreline maps or video tapes of south eastern Nova Scotia, Cape Breton Island, Prince Edward Island, south eastern and north western Newfoundland and parts of Labrador were carried out. Since this time all major oil discoveries have been made far offshore. Consequently, emphasis has been placed on gathering information on offshore biological data and fishing activity, since the east coast shorelines, apart from Sable Island have a very low risk of impact from offshore blowouts.

Maps of the seasonal distribution of marine resources and fishing activities have been prepared for environmental impact statements for Scotian Shelf and Grand Banks production development plans as well as from a major biological study on the Labrador Shelf. Government studies and assessments have provided offshore distribution maps for Georges Bank. The Department of Fisheries and Oceans regularly monitors and prepares summary reports on the distribution of fishing vessel activity throughout the east coast.

Offshore sensitivity mapping information is a valuable tool in the initial phases of an oil spill. The information provides an initial focus on resources at risk in the spill area. It assists planning for communications with fishing vessels, and for aircraft surveillance of spill movements and resources such as marine birds and mammals at risk from a spill. If the oil blowout is sustained the maps assist longer range planning of surveillance for marine species migrating through the spill region.

6.7 Environmental Effects Monitoring (EEM)

Environmental Effects Monitoring (EEM) is an important and necessary component of oil spill response and activities. EEM information collected during a spill identifies the effects of oil on the natural environment and commercial resources such as fisheries, and recreation areas. Physical and biological data collected during a spill provide information necessary to focus protection and containment, and cleanup operations efficiently, as well as to assess the direct and indirect impacts of a spill. EEM data collected during extended periods after a spill provide information on environmental recovery rates, especially for areas where different oil spill response procedures were deployed. These data are necessary to help plan response procedures for potential future spills.

Both industry and government agencies are involved in EEM studies during major spill events. The studies undertaken must be well planned and organized to achieve the required data under the difficult logistical conditions imposed by the spill itself. Preplanning for EEM studies is also difficult

because each spill introduces a unique set of conditions that must be accounted for in the study plans.

EEM studies require the availability of baseline environmental resource data from the impacted area for planning purposes. This information is available from resource sensitivity maps, commercial harvests and resource management research and development studies carried out by government agencies. EEM studies also depend on a reliable supply of both physical and biological data on the immediate and projected behaviour of the spill, the characteristics of the oil in the areas impacted and the populations and resources affected. These data sources provide the focus for EEM studies in the spill area. EEM study planning requires the involvement of scientists and technicians from government agencies and professional consulting firms, familiar with ongoing research and development studies, to plans and undertake the studies. Because EEM studies collect data for precise measurement, sophisticated equipment must be identified, procured and fitted into vessels, aircraft and vehicles. These activities must be undertaken with great care and with sufficient time to ensure that they will operate under difficult field conditions.

Owing to the constraints exposed by EEM studies they are usually not implemented for one to two weeks after the spill onset. On the other hand, they continue throughout the spill and into the past spill period to provide the long-range assessment of the spill impacts. EEM have been and will continue to be conducted during major oil spills in Canada and abroad. Within Canada co-operation between industry and government agencies (through REET during spill events) is both encouraged and necessary to ensure their success.

6.8 Response Personnel

6.8.1 Trained Company Personnel

The effectiveness of the response to major offshore spills is highly dependent on the knowledge, skills and capabilities of individuals on the response team. With the present low level of exploration activity in the Canadian offshore, the number of trained persons available to support and maintain the level of skilled work that must be accomplished during an emergency has declined substantially.

The following briefly reviews the status quo of some of the key positions for which company personnel require training.

Emergency Director: This position represents the executive levels within the involved company. Although the Emergency Director does not require in-depth knowledge of oil spill countermeasures, he must fully understand his role in a major oil spill incident, the specific roles of others in the response team, and the need to support and participate in pre-spill activities, including simulated exercises, that will improve his company's state of preparedness.

Most companies operating offshore have not provided specific training at the Emergency Director level. The exception might be those companies whose staff have developed extensive on-the-job training and experience at the Valdez spill.

Spill Superintendent: The person in this position, often called the On-Scene-Commander, is the company official who actually directs the spill cleanup operation on the field. This person needs an in-depth knowledge of all aspects related to spill response.

All companies operating offshore have staff who have received "On-Scene-Commander" training. The frequency of refresher courses should be reviewed within each company to ensure that this expertise is kept up to date.

Supervisors: These positions involve persons who will supervise, under the Spill Superintendent's direction, the highly specialized tasks of 1) physical recovery of oil at sea; 2) chemical dispersion; 3) shoreline cleanup; 4) disposal; and 5) surveillance and monitoring.

Companies are in generally good shape for the task of physical recovery because this function would be conducted by the Beaufort Sea Oilspill co-op or ESRI. The level of expertise within any one company in the other areas varies. Most companies rely on the services and advice of experts in other companies and contractors, depending on their availability. Not all existing contingency plans provide names of such individuals or assurances as to their availability in an emergency situation.

Foremen: These persons direct the workers who man the vessels, deploy the booms, operate the skimmers, etc. Foremen and workers who are employed by ESRI and the Beaufort Sea co-op are skilled and able to do their tasks efficiently and effectively insofar as their own equipment is concerned. Equipment brought into the response effort from outside would have to include operators who were equally skilled in its use.

Support Services: These include logistics superintendent, public affairs officers, safety and security staff, etc. As stated earlier, these persons are already experts in their required functions but do require an understanding of the basic elements of oil spill response and of their responsibilities during a spill. Training in applying these skills in a major spill response situation is required in most companies.

Spill Countermeasures and Spill Impact Experts: In the late 1970s and early 1980s, major companies operating offshore had at least two or three persons on staff who specialized in spill matters, kept the company's contingency plan up-to-date, advised on research programs and equipment purchases, and represented the company at meetings with government, symposia, field trials, etc. Many of these positions have been terminated since the downturn in the industry in the mid-1980s. A similar situation exists in government and the consulting industry, although the aftermath of the Valdez spill has produced a flurry of activity in all sectors.

It is clear then, that more company personnel need training in the various aspects of oil spill response. In 1986, government and the Canadian oil and gas industry recognized this by initiating an ESRF study to identify the training needs of the industry and to design an appropriate training program. The study determined that hands-on training, such as that provided by ESRI and the Beaufort Sea Oilspill co-op partially satisfied the needs of Foremen and workmen in a response effort, but that full training in all other positions was required.

Detailed curriculum and training courses were developed. The program curriculum was constructed using a modular format so that courses containing similar subject matter could use identical training modules, and separate modules could be used, as desired, by companies with in-house training programs. A total of 12 training modules were outlined, each described by means of detailed learning objectives. Recommended courses for each oil spill response position were identified.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 General Conclusions

7.1.1 Risk

To date approximately 385 wells have been drilled in Canada's offshore frontier lands and no major oil spills have occurred. At present offshore drilling rates, the expected frequency of large platform-based spills such as oil-well blowouts is very small - in the range of one spill per 300-1000 years of drilling.

7.1.2 Maximum Feasible Cleanup Capabilities

There is a maximum feasible capability associated with the at-source control and cleanup of very large oil-well blowout spills. These limits are related to environmental constraints such as sea states, ice, fog and darkness, and technological constraints such as limited capacities of even the world's best countermeasures systems, especially with respect to highly viscous waxy Grand Banks crude oil spills.

For Beaufort Sea oil-well blowouts (discharging 10,000 barrels of oil per day) the maximum-feasible amount of oil that can be removed at-source by physical recovery, in-situ burning and chemical dispersion, and by short-term natural evaporation and dispersion, is in the range of 82-93%. Oil spill dissipation times are in the range of 19-38 hours for open water spills. For blowout situations where the well products can be ignited because the drilling platform is seabottom-founded, virtually all the oil can be removed through burning.

For Grand Banks oil-well blowouts, the maximum-feasible amount of oil that can be removed at source is in the range of 19 to 62%, and most of the removal is due to at-source evaporation. Only 1.5 to 12 percent can be removed through cleanup measures. Oil spill dissipating times are in the order of weeks and months. However, it is highly unlikely that the oil would come ashore.

For Scotian Shelf condensate blowouts, virtually all the discharging hydrocarbons evaporate and dissipate at or near source, and no spill countermeasures are required except for surveillance and monitoring.

7.1.3 Industry Capabilities

In the Beaufort Sea, industry generally has the plans and equipment to respond effectively to oil-well spills to the maximum-feasible extent. Nevertheless, the Beaufort Sea co-op is re-evaluating its capabilities and will be making recommendations to provide an extra margin of protection.

On the Grand Banks, industry does not presently have appropriate equipment or sufficient support vessels to respond immediately to an oil well blowout and to clean up a blowout spill to the maximum-feasible extent. This is because industry's current suite of high capacity skimmers cannot handle the viscous waxy oils involved and because few ships are available to support the cleanup operation because of the low level of exploration and related activity on the East Coast. To address this situation, ESRI is developing recommendations for improving its capabilities.

In general, aside from the cleanup equipment deficiencies mentioned above, industry's response plans and methods (tracking systems, sensitivity maps, etc.) are generally adequate, but the level of personnel training and management involvement in oil spill response preparedness efforts requires improvements.

7.2 Specific Conclusions and Recommendations

7.2.1 Contingency Plans

Conclusions

Existing contingency plans are adequate for initial and short-term (one week) response actions, but are generally inadequate with respect to longer term, ongoing response requirements. Although exercises of response equipment and communication channels occur annually, exercises of the total plan, including company executive and managers and government decision-makers, have not occurred with sufficient regularity.

Recommendations

1) Companies should conduct assessments to identify anticipated manpower and other resources required to carry out prolonged and extensive oil spill response operations.

2) All key positions in contingency plans should have qualified, alternate/relief members identified.

3) For ongoing and/or extensive response operations, appropriate plans for delegation of authority, responsibility and tasks must be developed.

4) Contingency plans should be tested on a regular basis in company-simulated exercises involving all response team members. The exercises should focus on realistic scenarios.

5) Operators should implement "surprise" communications and mobilization exercises. These should involve regulatory agencies and other operators where appropriate.

6) Operators should participate in "paper" exercises with regulators to test linkages between company contingency plans and government plans.

7.2.2 Communications

Conclusions

Clear lines of communication for reporting incidents and ongoing liaison commitments for continuing incidents have been established and are described in company oil spill contingency plans.

Present offshore operations have adequate communication networks and capabilities to permit effective contact with all company-operated or managed aircraft, vessels and facilities. However, these communications systems will have to be expanded and enhanced in the event of a large-scale, prolonged incident.

Recommendations

1) Communication lines (described in contingency plans) should be exercised regularly.

2) Communication plans should be developed or reassessed for each of the offshore operation areas to identify hardware systems and communications personnel requirements needed to support large scale, sustained incidents.

7.2.3 Government Approvals

Conclusions

There are a number of areas (e.g., well ignition, priority areas protection, dispersant use) where delays associated with government approval could significantly hinder a spill response. Fast decision-making at the time of the spill or, better, pre-spill approvals to use a variety of techniques would improve the operator's ability to carry out a response effort.

Recommendations

1) Memoranda of understanding should be developed between appropriate government agencies to identify areas of responsibility and co-operation during spill response efforts. A single window approach for interacting with the government should be identified.

2) For those situations/techniques where government approval is required, discussions should be held with the relevant government agency to obtain pre-approval wherever possible and assurances of fast decisions where pre-spill approvals are not feasible.

7.2.4 Public Information Plans

Conclusions

A very large oil spill in Canadian offshore waters will receive great local, national and international attention which must be handled effectively. Companies require prearranged policies and programs for dealing with media, the public, governments and inter/intra industry communications and information needs that will arise.

7.2.5 Cleanup Equipment

Conclusions

Large caches of cleanup equipment are presently maintained at various locations in Canada. Their usefulness depends on the equipment's design, the type of oil spilled, and environmental conditions.

In the Beaufort Sea, environmental conditions and oil type are more conducive to equipment deployment, and expected oil recovery and response capability is relatively high. On the Grand Banks, where environmental conditions are more severe and oil is waxy, capabilities for recovering oil are very limited.

On the Scotian Shelf, oil type (condensate and light oil) reduces the need for conventional containment and recovery because the product will dissipate extremely rapidly. In spite of this, if equipment were required, it would be provided by ESRI.

Recommendations

1) Industry should continue its review of cleanup equipment capabilities and improve these where necessary. Serious consideration should be given to acquiring high-capacity, state-of-the-art recovery devices for co-op use to provide optimum first line response in both the Beaufort Sea and Grand Banks areas. Equipment should only be acquired where it can be shown that significant improvement in capability will result.

2) Industry co-ops and the Coast Guard should work together to maximize equipment compatibility and effectiveness.

7.2.6 Logistics Equipment

Ships

Conclusions

In the Beaufort Sea region, an adequate number of vessels are presently operational during the open water drilling season and would be available to support an offshore response effort.

On the Grand Banks, there are presently insufficient industry support vessels to mount an immediate response to a major oil spill incident.

Recommendation

A study should be undertaken for the Canadian east coast to determine the availability of alternate vessels and to identify pre-arrangements required to ensure immediate access to these vessels in the event of a major spill.

Tankerage

Conclusion

In the Beaufort Sea region and on the Grand Banks, there is suitable tankerage to provide offshore storage for recovered oil.

Aircraft

Conclusion

Both regions have adequate contingents of aircraft which could be supplemented on short notice as required.

Accommodation for Personnel

Conclusion

Both regions have sufficient existing infrastructure to accommodate the numbers of personnel required (200 to 300) to mount a sustained offshore oil spill response. Shoreline response, where required, would need additional support capabilities, but sufficient time would be available to establish the necessary infrastructure.

7.2.7 Spill Tracking

Conclusions

Effective technologies and systems are in place for tracking oil on the sea surface using airborne and shipborne platforms. There are inadequacies in the ability to track subsurface oil, oil under ice, and for determining the thickness and characteristics of oil.

Recommendations

Research should continue to improve capabilities to permit more accurate quantification and characterization of oil remaining on/under the sea surface and oil spilled under ice.

7.2.8 Oil Spill Modelling

Conclusions

Oil spill models are presently available to offshore operators. These permit general predictions of the movement of oil on the sea surface and are adequate for present spill response needs.

7.2.9 Environmental Sensitivity Mapping

Conclusions

Sensitivity mapping systems have been developed for both northern and eastern coastal and offshore areas and are adequate for present spill response needs. These systems ensure that response teams are well informed to make the best possible decisions regarding environmental protection priorities. At the time of an incident, available sensitivity mapping data will be augmented through the direct involvement of knowledgeable personnel, including the local public.

7.2.10 Company Training

Conclusions

In terms of oil spill response capability, there are insufficient numbers of knowledgeable and trained personnel in companies engaged in offshore oil and gas development in Canada. There has been insufficient involvement of senior management in planning and training for response to a major offshore oil spill.

An industry-wide training program was proposed and partially developed using industry funds prior to the downturn in activity. However, until such time as this training program is fully operative, industry should utilize other existing training programs to meet the recommendations which follow.

Recommendations

1) Each company should train an adequate number of employees in the various facets of oil spill response.

2) Senior management should participate in more general crisis management training to assist in developing internal crisis management teams and plans.

7.2.11 Additional Skilled Manpower

Conclusions

Even after training there may be insufficient skilled personnel in any single company to mount a response to a major, sustained oil spill in any offshore area of Canada. Additional response experts and manpower may have to be accessed in turn from regional, national and international sources. There are no established systems for efficiently accomplishing this.

Recommendations

1) To facilitate the efficient acquisition of additional experienced oil spill response manpower, a national directory of industry and contactor personnel should be developed and updated on a regular basis.

2) Through the use of CPA member companies, rapid spill response support (RSRS) listings should be established for each of the active offshore operating areas. These listings would be comprised of industry personnel with necessary expertise to respond to various key technical aspects of a major oil spill incident, and could be contacted on short notice by a member company.

7.2.12 Research and Development

Conclusions

The present state of development of best practical technology for dealing with major oil

spills represents the outcome of hundreds of millions of dollars worth of research conducted on a worldwide basis. Canada has been viewed as a world leader in the field of oil spill response research. The Canadian oil industry has played a major role in gaining this reputation by investing more than $30 million on offshore oil spill research over the last 20 years.

However, the amount of oil spill R&D funded by industry over the past 3 or 4 years (since the precipitous drop in the price of crude oil) has declined to very low levels. A similar drop in funding has occurred in government agencies.

Recommendations

1) Oil spill R&D programs should be funded by industry and government in Canada at a higher funding level that has been the case over the last four years.

2) The Canadian oil and gas industry should focus on R&D that will improve that industry's capability in particularly weak areas such as:

* technologies for recovering heavy, waxy and/or emulsified oil;
* chemical dispersant effectiveness;
* predicting the medium- and long-term behaviour and effects of Grand Banks crude oil spills;
* cleanup of oil in broken ice environments;
* in-situ ignition and combustion of water-in-oil emulsions;
* remote sensing to detect quality and quantity of oil spills in ice situations and for the tracking of Grand Banks crude oil spills.

SECTION III

ONSHORE OIL SPILL PROTECTION

SECTION III: ONSHORE OIL SPILL PROTECTION

1.0 INTRODUCTION

1.1 Objective

The Canadian Petroleum Association's (CPA) Task Force on Oil Spill Preparedness (TFOSP) Onshore Working Group consisted of twelve representatives from the petroleum industry who have had considerable experience in environmental management and oil spill response.

The onshore evaluation focused on various crude oil and condensate products associated with:

* Onshore exploration and development drilling wells in Western Canada, the Territories and Ontario.
* Production and processing facilities (wells, flowlines, and batteries) in Western Canada, the Northwest Territories and Ontario.
* Crude oil tanker truck traffic in Western Canada.
* Major oil transmission pipelines in the Northwest Territories and from Edmonton to Vancouver and Montreal.
* A ship loading terminal (from pipeline) in Vancouver, B.C.

The task force did not evaluate saltwater spills from production operations or oil and refined product spills from refining, marketing or marine tanker (ship) operations. However, the onshore working group did evaluate a crude oil ship loading terminal.

1.2 Methodology

Two industry survey questionnaires were prepared. Part A of the survey concentrated on an evaluation of contingency plans. Part B presented the following eight oil spill scenarios for both small and worst case spills:

Scenario # 1: Oil Well Blowout
Scenario # 2: Production Tank Overflow
Scenario # 3: Major Pipeline Rupture - Urban Area
Scenario # 4: Major Pipeline Break - River Crossing
Scenario # 5: Storage Tank Rupture
Scenario # 6: Ship Loading Terminal
Scenario # 7: Truck Rollover
Scenario # 8: Heavy Oil Spill into Creek

A series of questions addressing oil spill response measures accompanied each scenario. The questions were designed to investigate a company's or an oil spill cooperative's state of preparedness with respect to communication, company policy, response equipment,

contingency plans, training and prevention. All members of CPA and IPAC were requested to respond to the scenario survey. In addition, the survey was forwarded to members of oil spill co-ops in Western Canada, Ontario, Quebec, and the Atlantic Provinces, drilling and production companies in Ontario, and other interested parties. A total of 260 surveys were distributed.

The evaluation and interpretation of the responses that follows is the product of the combined expertise of the working group members, who have each been involved with oil spill response activities for many years.

1.3 Survey Response

The CPA and IPAC members who responded to the survey represent companies that produce approximately 70% of the 1988 gross Canadian hydrocarbon liquids production. The Working Group believes that the responses are representative of the state of oil spill preparedness in the industry in Canada.

A workshop was held for the working group members to review the responses. Comments and recommendations were then categorized into the following topics:

* Company Policy
* Prevention
* Communications
* Contingency Planning
* Equipment
* Manpower
* Training
* Research and Development

2.0 THE PETROLEUM INDUSTRY OIL SPILL ACTIVITIES

2.1 The Canadian Onshore Petroleum Industry

Prospective oil-bearing sedimentary basins have been identified off Canada's coasts and in the far north, but almost all of the crude oil produced today comes from the western provinces, the so-called Western Canadian Sedimentary Basin. Alberta is by far the largest producer of crude oil in Canada. The other provinces with producing status are: British Columbia, Saskatchewan, Manitoba and Ontario. Except for the Norman Wells oil field and limited production from Bent Horn in the Northwest Territories, reserves of oil in the rest of the country are not in commercial production. The following table represents the number of producing oil wells as of December 31, 1988:

Area	Production Oil Wells
British Columbia	673
Alberta	22893
Saskatchewan	13916
Manitoba	1370
Ontario	1170
Northwest Territories	159

When oil flows out of the well, it is usually piped to a battery or nearby tanks. Gathering lines or tank trucks then deliver it to feeder pipelines or the major transmission lines for shipment to

refineries and for export. In Canada, there are 37,300 km of gathering and transmission oil pipelines.

The major transmission line is the Interprovincial pipeline system which stretches from Edmonton through five provinces and six U.S. States to Montreal. The Trans Mountain pipeline system moves crude from Edmonton through Kamloops to Vancouver and northwest Washington State. Canada's most northerly oil pipeline, the Norman Wells pipeline, ties the Norman Wells oil field to the southern pipeline network at Zama, Alberta.

2.2 Oil Spill Prevention

The CPA is a national focal point for industry's efforts in handling oil spills. The CPA deals with the protection of the environment in the 'upstream' activities of exploration, production, pipelining and ship loading terminals (connected to pipelines). Recognizing the need for environmental protection, the CPA has developed a Code of Practice which recommends that: environmental planning should be an integral part of the planning process; the industry should ensure minimum impact on the environment, public health and safety by using the best practical technology; and the industry should consult with communities about their concerns regarding industry activities.

The Canadian oil industry spends millions of dollars each year to ensure that its drilling, production, operating and transportation systems are in compliance with existing regulations and that its facilities are operated as efficiently and safely as possible. Prevention of all spills is a major goal within the industry. However, it is difficult to have perfect conditions at all times given the number of facilities in existence. Companies must be prepared to utilize proper construction and operational procedures along with adequate maintenance, inspection and training programs if prevention is to be attained.

2.3 Contingency Plans

A contingency plan is an action plan and guide for emergency procedures, notifications, responsibilities, emergency equipment locations, oil spill control points, safety, media and reporting requirements. The most effective responses are developed from repeated experiences. To be effective, employees must be well-trained and understand the purposes of their plans. This is accomplished through regular communication exercises and the analysis of various emergency (oil spill) scenarios which may be possible at their facilities.

Several types of contingency plans are used in the industry. Some are specific to drilling, sour gas or oil spills while others cover all types of emergencies with reference sub-sections on the specific areas. Oil spill contingency plans are not an operational requirement in all regulatory jurisdictions. However, the industry continues to practise prevention by formulating contingency plans in all regions of Canada.

2.4 Oil Spill Equipment

When an oil spill is reported, an immediate hazard assessment is conducted followed by the shutting-in of the source and the containment and recovery of the oil. The primary containment devices on water are containment booms. They are essential tools in any oil cleanup program on water and are generally the first equipment mobilized at the scene and the last to be removed. Booms can be generally described as a barrier that extends above and below the water

surface designed to stop or divert the flow of oil. Once contained, skimmers and sorbent materials are used to recover the oil. Skimmers are any mechanical device designed to remove oil from the water surface without causing major alterations in its physical or chemical properties. A series of pumps and hoses is used to transport the oil to storage tanks.

On land, earth-moving equipment is usually used to build dikes or trenches for containment, and vacuum trucks are used to recover contained oil.

2.5 Training

On a national basis, more than 3000 industry, contractor and government personnel annually attend oil spill equipment exercises as observers or equipment crew members. However, training in spill prevention, contingency planning, control point selection and media relations are also crucial to an effective response program. Training programs in North America for onshore oil spill preparedness are available from the following institutions and oil spill co-ops:

Institutions (formal training)

* Petroleum Industry Training Service, Calgary, Alberta
* Lambton College, Sarnia, Ontario
* Texas A & M University, Galveston, Texas
* Corpus Christi State University, Corpus Christi, Texas

Co-ops (informal training)

* Canada West Petroleum Association
* Canadian Petroleum Association
* Ontario Petroleum Association
* Quebec Petroleum Association
* Atlantic Petroleum Association

Companies (in-house training)

2.6 Research and Development

In the past, industry has initiated research and development work on new containment and recovery technologies. This work has resulted in the development of a disc anchor for anchoring equipment on lakes and rivers, a mobile air curtain incinerator, an oil debris separation tank, and the development of ice slotting techniques for the recovery of oil from under river ice. As not all oil spill situations will allow for the safe deployment of response equipment, the industry has also developed shoreline cleanup guidelines.

2.7 Oil Spill Response

The petroleum industry has national, regional and local organizations ready to respond to oil spills Prevention of spills is a prime concern, but when they occur, it is essential that the most effective containment and clean-up procedures are quickly available. A company's most immediate defence is its own oil spill equipment and manpower resources. Should additional assistance and equipment be required, a regional oil spill co-op can be called in to provide assistance.

In Western Canada, 31 industry-sponsored co-operatives have been organized in the Prairie Region to protect specific geographic areas, gathering systems, production facilities and major transmission pipelines of the upstream sector of the industry. The co-ops keep oil spill equipment on hand for common use, and rely on operating personnel from nearby production facilities to deal with spills in the local region.
The 31 co-ops in the Prairie Region are:

Northeast British Columbia	1
Alberta	23
Saskatchewan	6
Manitoba	1

If the co-op equipment is insufficient, the company can utilize the Prairie Regional Oil Spill Containment and Recovery Advisory Committee (PROSCARAC) equipment contained in 9 Oil Spill Containment and Recovery (OSCAR) semi-trailers. PROSCARAC, a CPA committee, besides administering the OSCAR units, provides training for company members and conducts research and development work.

PROSCARAC administers the 9 OSCAR trailers and 3 Canada West Petroleum Association (CWPA) trailers on behalf of the CPA, IPAC and CWPA. CPA supervises the contractors who are directly responsible for maintenance of the trailers and equipment. Members of PROSCARAC and associate members (which include federal, provincial, municipal agencies) have access to the OSCAR units without charge. Non-members are charged a unit rental fee and a percentage of individual equipment replacement costs.

When a CPA or IPAC member transports its crude oil and condensate outside the main 'upstream' production areas of northeastern British Columbia or the prairie provinces, the company must either rely on its own internal resources of equipment and manpower or that of 'downstream' industry associations. This is also true for companies that produce crude oil in other onshore areas of Canada, primarily Ontario. In British Columbia, assistance in the non-production areas of the province is available from the Canada West Petroleum Association (CWPA). In Ontario and Quebec, assistance is available from either the Ontario Petroleum Association (OPA) or the Quebec Petroleum Association. Membership in these downstream industry associations is open to companies that manufacture, market or distribute petroleum products at the wholesale or retail level.

As with the CPA, the Ontario Petroleum Association (OPA) provides immediate response to spill incidents through equipment co-ops. There are 10 co-op areas located throughout Ontario with 27 oil spill equipment units. Training programs are held throughout the year with hands-on exercises and classroom sessions for members, the OPA co-ops and local contractors. The Petroleum Industry Marine Environmental Co-operative (PIMEC) was established by industry for response to oil spills in the river systems of the Great Lakes.

Through the establishment of the oil spill co-ops and industry associations, CPA and IPAC have ensured that all operators, regardless of their size, have the resources to develop effective oil spill response procedures.

2.8 Spill Statistics

Spill statistics can help the petroleum industry identify potential spill sources and trends. Programs can then be implemented to prevent or mitigate the impacts of future spills and the potential for causing environmental damage.

For the purposes of discussion in this report, small spills are considered to be 10 m^3 or less and are contained on the company lease. Medium spills, usually off-lease, are up to 100 m^3, and large spills are above 100 m^3. A worst case spill for the industry is Scenario # 5 where 20,000 m^3 of oil is released. However, any size spill could be considered a worst case if it occurs under certain conditions.

The key to obtaining valid statistics is the accurate reporting of spills. The longer that a jurisdiction has required the reporting of oil spills,

the more compliance is in evidence. In Alberta, the Energy Resources Conservation Board (ERCB) estimates that nearly 100% of all oil spills are now reported. Nationally, Environment Canada believes that 90% of the larger spills and 20% of the smaller spills are reported; however these national figures are not inclusive to the 'upstream' petroleum industry. Statistical averages are also affected by single significant events and the concentration of the pollutant in the reported release volume.

The ERCB has indicated that, since 1984, the number of reported oil spills in Alberta from all types of facilities has increased. However, the numerical relationship between cause and source has remained the same. The ERCB attributes the increase to stricter spill reporting requirements, a greater effort by government to inform public and industry of oil spill reporting requirements, and an increase in environmental awareness by both industry and public. During the same period, reported spills from pipelines have decreased. In jursidictions other than Alberta, the number of reported spills has remained constant or shown a slight increase.

Nationally, Environment Canada data for the years 1980 to 1983 (the last published data) indicate that crude oil spills account for 27 to 35% of reported spills of all materials. However, the amount of crude oil spilled still represents only 1 to 4% of the total tonnage of all materials spilled annually.

In the producing Western provinces, the reported volume of oil spilled compared to oil produced for the years 1984 to 1988 has approximated 1 litre spilled per 10,000 litres produced.

The source and cause of liquid hydrocarbon spills has also remained relatively constant for the years 1984 to 1988:

Source	**% of Spill Reports**
Pipelines	52%
Production Facility	21%
Wells	19%
Miscellaneous	8%

Cause	**% of Spill Reports**
Corrosion	50%
Equipment Failure	27%
Human Error	15%
Miscellaneous	8%

Statistics on oil spill source and cause have helped industry to focus on preventative measures in specific areas. Most spills can be classified as small and occur on land where environmental damage is minimal and immediate reclamation of the contaminated site can be undertaken. Pipelines have a proven track record as the safest means of transporting hydrocarbons. The frequency of pipeline breaks is low, considering the thousands of miles of pipelines and flowlines and the fact that many lines carry corrosive fluids at high pressure through difficult terrain. The most recent performance records indicate a 10 year average of 1 litre of oil spilled per 35,000,000 litres shipped per kilometre of pipeline.

2.9 Oil Spill Consequences

The effects of an oil spill can be very dramatic in the short term and can give rise to the anxiety of damage being permanent. For onshore activities, large spills may not result in the most significant environmental effects. A small spill in a sensitive area can be as damaging as a large spill into a moving waterbody. The most effective response will result in containing the oil to a limited area and thereby minimizing contamination. Removing oil quickly from both land and water using safe and effective methods will also help to reduce the impact.

The consequences of a spill can be both short- and long-term. The short-term effects include visual impact, immediate damage to plant and animal life and the fouling of water supplies for downstream users. Affected land will have restricted use until the oil has biodegraded. Water sources will be monitored for contamination and, if necessary, alternate water supplies will be used.

The long-term effects will depend upon the effectiveness of the response and cleanup procedures, terrain and climatic conditions. In most cases, areas which have colder ambient temperatures will require longer periods of time for reclamation. Surface water contamination will not usually be a long-term problem, however, contaminated groundwater may require years for purification.

Oils can be biodegraded in soils by enhancing the bacterial activity in the spill area and removed from water using air stripping and charcoal filtration.

The combination of an effective initial response and the appropriate cleanup and reclamation procedures will help to reduce an oil spill's long-term environmental and social impacts.

3.0 DESCRIPTION OF SPILLS

3.1 Types of Oil

"Oil" is a general term used to describe a wide variety of natural substances of plant, animal, or mineral origin, as well as a range of synthetic compounds. Each oil type has specific physical and chemical characteristics that influence its behaviour when spilled, the resultant biological effects, and the most practical and efficient cleanup techniques. Crude oil consists of two portions: a very volatile or light fraction from which gasoline-like materials can be obtained (referred to as condensate), and a heavier portion which yields products such as diesel fuel, lube oils, asphalts and waxes. For example, Norman Wells crude is very light, whereas crude produced in the Lloydminster area is generally heavy and has a consistency similar to tar. Canadian oil fields produce numerous types of crude oils, and for this reason, industry has developed a wide variety of techniques and equipment to combat spills.

3.2 Characteristics of Oil

The physical and chemical characteristics of oil that affect its behaviour on land and water and influence the efficiency of cleanup operations include specific gravity, viscosity, surface tension, pour point, flashpoint and solubility in water. These parameters may vary over time as the oil weathers or is affected by ambient conditions.

3.2.1 Specific Gravity

Specific gravity is the ratio of the mass of a substance to the mass of an equivalent volume of water. The specific gravity of an oil is a measure of its density and affects its ease of dispersion in water. Since the specific gravity of virtually all oils is less than 1.0, they will float on water. The only exceptions to this rule are certain heavy crudes and residual fuel oils. The specific gravity of spilled oil will increase with time as volatile fractions evaporate, and it may actually exceed 1.0 after considerable "weathering", causing the oil to sink below the water surface.

3.2.2 Viscosity

Viscosity is a measure of the flow resistance of a fluid; the lower the viscosity of a substance, the easier it flows. Viscosity, like other physical characteristics of oils, is also affected by temperature; the lower the temperature, the higher the viscosity. The viscosity of an oil is mainly governed by the proportion of lighter fractions it contains as well as the ambient temperature. In terms of oil spill cleanup, viscosity influences the spreading rate of a slick, the stickiness of the oil, its penetration into soil or sediments and the ability of pumps to remove oil from the surface.

3.2.3 Surface Tension

Surface tension is the force of attraction between the surface molecules of a liquid. This force, together with viscosity, affects the rate at which an oil spill spreads over the water or land surface or seeps into the ground. The lower the surface tension of an oil, the greater its potential spreading rate.

3.2.4 Pour Point

The pour point of an oil is the temperature at which it becomes a semi-solid or "plastic" and will not flow. This is caused by the formation of an internal microcrystalline structure and overrides the effects of viscosity and surface tension. For example, gasoline spilled on water will remain a liquid, whereas a heavy crude oil may become a solid once its temperature is lowered to that of the water. The pour point of an oil is one of its most important characteristics in terms of impact to the shoreline and subsequent cleanup.

3.2.5 Flash Point

The flash point of an oil is the temperature at which its vapours will ignite when exposed to an ignition source. This is an extremely important factor in relation to the safety of cleanup operations. Many freshly spilled crude oils are dangerously volatile until the lighter components have dispersed or evaporated. Bunker and heavy fuel oils, on the other hand, do not cause a serious fire hazard when spilled, and in fact, tend to be difficult to burn during cleanup operations.

3.2.6 Solubility

Solubility is the process through which a substance can be dissolved in a given solvent, in this case, the dissolution of oil in water. It should be emphasized that the solubility of oil in water is very low (generally less than 5 parts per million). Nevertheless, the low solubility of oil in water constitutes an extremely important process in relation to the potential toxicity of hydrocarbons to aquatic organisms.

3.3 Behaviour of Oil

The natural events that take place following an oil spill include spreading of the oil slick and its gradual weathering. It is important to note that the behaviour of an oil slick is highly dependent on the type of oil spilled and on the ambient climatic conditions.

As a general rule, the oil slick spreads quickly immediately following a spill. During this initial period of spreading, when the force of gravity has an important role, the spreading rate tends to be a function of the volume of oil spilled with large spills spreading faster than smaller ones.

3.3.1 Oil on Land

When oil is spilled on land, it may spread on the surface of the land or it may penetrate into it. The direction and extent of spreading will be affected by the slope of the land, the viscosity of the oil, temperature of both product and environment. Oil movement is affected by the soil type, (e.g. clay vs sand or gravel), location of water table, dryness of the soil and presence or absence of frost in soil. The presence of vegetation will also affect the extent and rate of spreading. Dry grasses and vegetation will soak up oil readily and limit spreading.

3.3.2 Oil in Land

Oil tends to migrate downward until it reaches a water table, rock, or similar impervious barrier, and it then follows that barrier in a downslope direction. The spilled product could resurface at a location distant from the spill, or it could remain at the spill site. It could also follow the direction of groundwater flow and contaminate groundwater supplies at some distance from the spill. The porosity of the soil will affect the extent and rate of spread. It will migrate much more rapidly in sand than in loam or clay. Some clays and silts provide a significant barrier to oil.

3.3.3 Oil on Water

The specific gravity of most oils is less than water. This will result in an oil slick which floats on the surface of the water and has the potential to spread rapidly. Heavy crude oils however may sink or form 'tar balls' which are suspended below the surface of the water. The horizontal spreading of oil over the water surface will occur even in the complete absence of wind and water currents and is caused by the force of gravity and the surface tension of water. As time passes and the slick naturally spreads into a thinner layer, the force of gravity has a decreased role in perpetuating the spreading process. Further slick spreading does not depend on the thickness of the oil film, but rather on differences between the oil and water surface tension forces.

Wind, waves and currents add energy that can result in the formation of oil-in-water or water-in-oil emulsions. Oil-in-water emulsions generally result in the total dispersion of the slick into the water column. The water-in-oil emulsions (chocolate mousse) are generally very stable but create additional clean-up problems because they are difficult to pump and increase the volume of materials to be recovered.

In addition to the natural spreading tendency of oil, a slick will move in the same direction and at the same speed as the surface water. Currents and winds are the major factors governing surface water movements. In general, an oil slick will move at a rate approximately 3% of the wind velocity. The presence of excessive surface debris will also affect movement of an oil slick.

3.3.4 Oil On Or Under Ice

Most oils spilled onto ice have a tendency to spread, subject to surface irregularities and viscosity of the oil. A significant volume of some oils can be absorbed into porous ice. The presence of oil on, or in, ice increases the rate of absorption of solar energy and hence the rate of melting. Subsequent freezing and melting may eventually cause the oil to migrate throughout the thickness of the ice.

Oil spilled under ice floats up against the underside of the ice and collects in pockets or irregularities. In the presence of currents, oil will become mobile and move to new locations. The degree of movement will be affected by irregularities under the ice as well as the currents. Subsequent freezing may also trap oil in the ice layer causing migration towards the surface.

3.4 Fate of Oil

Oil spilled on water or on land undergoes a progressive series of changes in physical and chemical properties which, in combination, are referred to as "weathering". The weathering of oil starts immediately after it has been spilled and proceeds at rates that vary according to the type of oil involved and ambient climatic conditions. Weathering rates are not constant throughout the duration of an oil spill and are usually highest in the first few hours. The process of weathering occurs simultaneously with the spreading and movement of an oil slick.

Major processes that contribute to the weathering of oil spills include: evaporation, dissolution, oxidation, emulsification, and microbial degradation. In effect, weathering is the loss of certain components of the oil through a series of natural processes which begin when the spill occurs and continue indefinitely while oil remains in the environment. The lighter and more volatile components of the spilled oil are lost most rapidly. Consequently, the rate of weathering is highly dependent on the type of oil spilled; light crudes and fuel oils typically weather at a much faster rate than heavy crudes or heavy fuel oils which contain a smaller proportion of light fractions.

3.4.1 Evaporation

Through the process of evaporation, certain fractions of the oil are lost to the surrounding atmosphere. The lighter hydrocarbons will, of course, evaporate more rapidly than heavier components of the oil. The rate of evaporation depends primarily on the volatility of various compounds in the spilled oil but is also significantly influenced by factors such as air and water temperature, water turbulence, wind, and the spreading rate of the slick. In the case of crude oil, evaporation accounts for the largest proportion of its volumetric loss after a spill; evaporation rates of 25% of the total volume of spilled crude within one day are not uncommon. As might be expected, evaporation plays an extremely important role in gasoline or light crude spills. Gasoline evaporates by about 50% of its original volume within 7 to 8 minutes at 20° C and may create a tremendous fire hazard since the ignition potential in the surrounding atmosphere becomes extremely high.

3.4.2 Dissolution

Dissolution starts immediately after an oil spill, and unlike evaporation, it is a long-term process which continues throughout the duration of the total weathering process. This is due to the fact that oxidation and microbial degradation of the oil

constantly produce compounds that are water soluble.

3.4.3 Oxidation

Oxidation of certain hydrocarbons produces other compounds that are water soluble and subsequently dissolve in the surrounding water. Some of the products of chemical oxidation may also act as emulsifiers and increase the dispersion of the spilled oil. When the oil is spread into a relatively thin film, photo-oxidation may result in the weathering of as much as 1% of the spilled oil per day, depending on latitude and light intensity.

3.4.4 Emulsification

Emulsification is the process by which one liquid is dispersed into another liquid in the form of small droplets. In the case of oil, the resulting emulsion can be either oil-in-water or water-in-oil. Emulsification is an important factor in the physical dispersion of oil spilled in water, and has an important role in both the weathering of oil and its subsequent cleanup. While there are important differences in the properties of each emulsion type, both oil-in-water and water-in-oil emulsions are formed as a result of wave action.

Once oil-in-water emulsions are formed, other weathering processes such as dissolution, photo-oxidation and biodegradation may be accelerated due to the large increase in the surface area of the oil relative to its volume.

3.4.5 Biodegradation

Virtually all gaseous, liquid and solid hydrocarbons are attacked by micro-organisms. Many species of bacteria, fungi and yeasts oxidize petroleum hydrocarbons through the use of these compounds as food sources. More than 100 species of bacteria, yeasts and fungi have been shown to degrade hydrocarbons. The rate of biodegradation is primarily dependent on the temperature of the oil and water/soil strata. Generally speaking, rates of degradation tend to increase in a direct proportion to temperature.

3.5 Effects of Oil

The effects of an oil spill can be very dramatic in the short term and usually give rise to anxiety that damage may be permanent. Visual impact is a prime concern in amenity areas, and unless the oil is deliberately removed, it may remain visible for years. If the initial response to a spill is handled quickly and effectively then long-term problems will be minimized. The type of oil and certainly the volume spilled will be an important factor in the overall effect. The light end fractions of crude oil are usually more poisonous to plant and animal life than are the heavy ends. This is due primarily to their water solubility and their ability to penetrate surface tissues. The heavy fractions do more damage to soil and living organisms by smothering or preventing the exchange of air, water and nutrients.

The total effect of an oil spill on soil is dependent upon the interaction of many factors, including the volume and type of oil spilled, the time of year of the spill, the moisture content and type of soil, drainage and topography of the area. The light fractions are often toxic to bacteria and fungi which live in the soil, and it is these organisms that will degrade the oil if managed properly. As the light ends evaporate the heavier components are left as a residual crust of oil on the surface. This crust will interfere with normal gas exchange at the surface and may lead to unfavourable

anaerobic soils. As well, normal wetting and evaporation of water will be interrupted by the crust so that a dry soil will remain dry, and a wet soil waterlogged.

The structure of the soil may be affected, depending upon the type and amount of oil spilled, and on the type of soil (e.g. tilled agricultural versus forest soil). Similarly, soil pH may also be affected by oil spills, depending upon the oil type. Often oil will help buffer the soil near neutrality, but sour crudes lead to acidification of the soil through oxidation of sulphur compounds.

With careful management of certain factors, the impact of an oil spill can be lessened and the recovery rate hastened by utilizing the oil-degrading micro-organisms normally found in soil.

When oil enters surface water or groundwater, a portion of the light fractions will dissolve in the water. In addition, chemicals and salts present in the oil will also dissolve resulting in possible contamination. If this water is available for irrigation, livestock and human consumption, it would have to be tested prior to use. A small amount of hydrocarbon can give a noticeable odour and taste to the water. In most cases, this can only be removed through excessive dilution, aeration or charcoal filtration. Most plants are affected as the light ends will penetrate the stomata, and the root system will take in the soluble fraction which dissolves in the water. Oil may also cause destruction of the protecting waxy cuticular layer and interfere with the active transport of nutrients. Heavy oil will have a smothering effect unless the oil is removed within a few days.

Toxicity of hydrocarbons can be related to factors other than direct solubility in water. Animals that are oil-wettable, such as most insects and insect larval, die very quickly in oils. Oil is easily absorbed, either through the intact cuticle or via the spiracles, or is ingested, and great discomfort and even death to fish and aquatic insect larvae can result from the reduction of available oxygen. If an oily layer covers a pond, oxygen cannot redissolve in the water, so a state of oxygen shortage can develop. Other mammals, and waterfowl that become oil-wet, such as muskrats, beaver, ducks, and geese, die of exposure. A coating of oil on fur or feathers destroys the insulating properties and hypothermia results.

4.0 COUNTERMEASURES

Once an oil spill has occurred, it is recognized that a prime objective is to shut in the source of the spill and contain the product to prevent further migration and contamination. If the containment and recovery process is properly implemented then cleanup procedures can be simplified. The order in which these tasks are conducted will depend upon the individual circumstances of the spill, however the **safety** of the personnel involved is most important and must be considered over and above shut-in and containment procedures.

No two oil spills are exactly alike. The behaviour of oil on water, land or during winter conditions can vary to a large degree. The ability of the personnel involved to contain and recover spilled material is dependent upon their training and experiences in field situations. Factors such as the type of oil, volume of the spill, weather conditions, available equipment, and other environmental factors will play an important role in containment and recovery procedures.

4.1 Containment and Recovery on Land

When oil is spilled on land it may spread out over the land surface and move laterally towards a low-lying area, or it may penetrate into the soil layers immediately below the spill site and then move laterally along porous seams such as gravel or backfill material (i.e. sand). In some spill situations, both events occur, making containment and recovery methods extremely difficult. Surface lateral movement of oil is dependent upon the slope and type of surface cover (eg. grass), volume spilled, type of product, and the temperature of the oil and environment.

The most common method of containment involves the construction of a dyke or trench around the spill area. This can be done using a backhoe, tracked vehicle or similar piece of equipment or by manual labour using hand tools.

Oil that collects in the trench and bellholes is recovered using suction units such as vacuum or tank trucks. In special circumstances, explosion-proof pumps and skimmers may provide a higher level of efficiency and safety.

In some cases, oil may penetrate the soil to a depth that restricts the use of conventional trenching. If this should happen, it may be necessary to drill recovery wells around the spill area to the necessary depth so that the fluid can be intercepted and brought back to surface using special downhole pumps.

4.2 Containment and Recovery in Wet Areas

Containment and recovery of oil in wet areas, such as muskeg, can be the most difficult of all the land-based spill operations. This is due to the type of soil and vegetation cover that exists in wet areas and the limited access by heavy equipment and manpower. Many wet areas contain soils that are high in organic matter. In some cases, this material can be metres thick. In addition, the organic layer will hold moisture similar to a sponge and, unless severe drainage techniques are used, will remain wet.

Water levels in these areas will fluctuate depending upon muskeg type, time of year, and source of water. Spills that enter wet areas during high water periods can be easier to deal with, as the water will reduce the amount of contact area between oil and vegetation. High water, however, may restrict access making containment and recovery more difficult.

The most effective methods for containment include the construction of an earthen dyke and weir unit or some type of flow through system known as a filter fence. Both of these techniques allow for the movement of water from the spill area but contain the surface oil and can be modified to contain heavy oil which sinks to the bottom of the wet area.

Oil contained on the upstream side of the barrier can be collected using vacuum or tank trucks, and if the water depth is greater than 30 cm, some skimming devices may be used. In areas

where access to the spill site is extremely difficult and construction of containment devices will create more environmental damage, burning of the oil will be considered as an option.

4.3 Containment and Recovery on Moving Waterbodies

Most oil spills on water spread rapidly to form thin layers or sheens. The rate of spreading is dependent upon factors such as wind and currents. When oil enters a waterbody, the slick will move with the water at the same speed as the surface current unless there are strong environmental factors acting in the opposite direction. Every effort must be made to slow this movement so that the oil can be recovered. Containing and recovering oil on fast moving waterbodies such as rivers or streams is generally the most difficult of all water situations. In most cases, containment procedures utilize conventional booms which are deployed in a variety of configurations.

If a boom system is stretched from one shoreline to the other, and at right angles (90°) to the current, the chances of containing oil will be decreased.

At current speeds greater than 1 km/hr, vortices (whirlpools) and entrainment (oil droplets shearing off from the underside of the oil layer) will drag the oil down beneath the boom skirt rendering the containment ineffective. In fast currents this problem is reduced by angling the boom in relation to the current. The surface restriction is minimized permitting the oil and water to move downstream along the leading edge of the boom and into the recovery area. The angle at which the boom is set is dependent upon the speed of the current and in most cases will vary between 10° to 45°. As the current speed increases the angle which is placed on the boom decreases.

This method is referred to as the "V" configuration of boom deployment and, when integrated with a skimmer of adequate capacity, creates a system which is reliable under most conditions. In some river systems, the surface velocity may exceed the capability of the containment boom causing boom failure. In these circumstances, alternate containment and recovery sites known as "Control Points" are selected.

On moving water, the primary objective is to divert the oil from the fast water area to the shoreline where current speeds are slower. The area will allow skimming devices to function more effectively and provide for safer operation. The "V" concentrates the oil layer to a certain extent so that the recovery process is more efficient. The flow rate and volume that a skimmer must handle can be very significant, therefore, the unit incorporated into the overall system should be designed for fast water conditions (i.e. Pedco Barrel Skimmer). The pumping system as well, must be able to handle the volume and type of product being recovered. In most cases, a centrifugal pump used in conjunction with the Pedco skimmer is an adequate means of oil recovery, however, other skimmers are available for use if the conditions are right. The recovered fluid is directed to tank trucks or holding tanks until final disposal or recycling is determined.

Many of the river systems encountered may contain large amounts of ice, logs and tree branches at various times of the year. This debris can interfere with recovery operations by

plugging skimmers and can damage conventional boom systems. The debris will follow the diversion line of the boom and may become entangled in the shoreline bridles and ropes. This excess pressure on the boom may cause mechanical failure. In addition, the damming effect of the debris may cause turbulence resulting in oil losses. It is, therefore, important to separate the debris from the oil prior to entering the recovery area, and this is best accomplished by using a debris deflector upstream of the containment boom.

There are two methods of removing debris. The first method deflects the debris into the main channel of the river where it is allowed to float away from the area. This method eliminates the need for removing the material, however, some oil may also be carried through with the debris. The second method deflects the debris to shore upstream of the main recovery area where the material is removed by hand or with the use of backhoe. Some oil may be entrained with the debris, but once the material has been removed, the oil can be recovered without much difficulty.

As the volume and size of the debris increases, the effectiveness and safe deployment of the containment system is reduced and under severe stress will fail. There are no options available under these circumstances which will prove satisfactory for containment and recovery. Shoreline cleanup will be implemented when the conditions allow. Heavy and weathered oils which sink below the surface of the water and migrate along the river bed will also be difficult to contain and recover as current spill response equipment is designed to function on or near the surface. In shallow river systems up to the depth of one metre, some modifications to existing equipment may allow for oil recovery however, in greater depths this too will prove ineffective.

4.4 Containment and Recovery on Stagnant Waterbodies

Containment and recovery procedures on stagnant waterbodies such as lakes and sloughs can also be difficult to implement. Oil on water forms a slick and spreads into shapes dictated by surface currents and winds. A circular slick is formed when there are no significant surface currents or winds. An elliptical shape is formed by moderate surface currents and winds. High winds and strong currents will create a more triangular-shaped slick. The triangle will widen (spread) as the slick moves away from its source. Wave action, generally caused by wind, will rapidly distort these shapes, eventually forming streamers or windrows of oil. Therefore it is important to try to contain an oil spill before it becomes too wide for effective containment.

The direction of wind and currents is considered when selecting a recovery area and these sites should be located downwind of the spill source. Winds or lake currents may assist recovery operations by concentrating the slick on one shoreline. In calm conditions, the oil slick will spread over the water surface and near the source of the spill. In open water conditions, the slick will be contained and concentrated using a boom formed in a "U" configuration. The oil is then recovered by either bringing the slick closer to shore so that conventional skimmers can be utilized or by taking the recovery and storage units to the slick.

In situations where environmental factors are moving the oil slicks to shore, precautionary measures are taken to protect the shoreline against oil contamination. If this process is successful, it can greatly reduce the amount of area that will have to be cleaned after recovery is completed. This can be accomplished by placing barriers such as conventional booms, sorbent booms or sorbent mats along the shoreline prior to the oil's arrival. Once the slick has been brought to shore, a second boom can be place on the opposite side of the slick so that it is fully contained. This procedure will prevent further migration should the wind direction change or if waves are generated by the boat prop wash.

In some cases, it may be necessary to contain the oil in open water and transport it to shore for recovery. This method is commonly used when the available equipment is not suitable to handle offshore recovery techniques or if the water depths are not sufficient to allow large equipment to function properly. The oil slick is surrounded using a conventional boom and boats to form a "U" configuration or "catenary". The catenary is towed toward the recovery area at a very slow rate as too much speed will put excessive perpendicular force on the boom skirt causing oil to be drawn underneath.

Recovery of the oil is accomplished through use of vacuum trucks or stagnant water disc and rope skimmers. Another method involves towing a boom and skimmer configuration through the oil slicks using two tow boats followed by a work barge which is equipped with pumps and storage containers.

As the oil enters the wide part of the "V", it will contact the two diversion booms and be directed into the skimmer. Containment and recovery on open water is very dependent upon wave conditions. Excessive wave height will hamper most booms and skimmers resulting in less oil recovery. Strong wave action can also create safety concerns for the boat operator and crews.

4.5 Containment and Recovery During Winter

Oil spilled during winter or cold weather conditions can be very difficult to contain and recover as the oil tends to accumulate under snow and ice layers. Some ice surfaces are quite porous and may absorb a significant volume of the light ends. The viscosity of the oil due to the lower temperatures may prevent the oil from migrating as far and fast as during warm conditions.

Spills which originate on land can be contained using dykes and trenches and are best recovered by vacuum trucks. Oil spilled under solid ice will collect in pockets or irregularities on the underside of the ice surface. Any movement of water in the form of currents or man-made turbulence will cause the oil to break away from the ice and migrate downstream or away from the turbulent area. In most cases, oil will surface into holes or slots where it can be recovered more easily. The ice must have adequate thickness to support the weight of men and equipment used for containment and recovery.

If the spill occurs in a stationary waterbody, the resulting subsurface oil layer should remain as a relatively concentrated mass near the point of entry or break. The nature and extent of the contamination will depend upon the type and

amount of product spilled and the subsurface roughness of the ice. Collection trenches or slots can be constructed using trenching machines, ice saws, chain saws, or other mechanical devices. Smaller holes can then be drilled through the ice in the spill area and recovery equipment such as skimming heads or suction hoses installed.

Oil that is trapped beneath ice layers in moving water situations is best contained using an ice slot or trench. The slot is angled to the current in a fashion similar to that of a conventional boom. As the oil reaches the slot, it surfaces and is directed to shore by the current which has established in the slot. The recovery process can be enhanced by physically moving the oil layer using air or water. A current is produced directly below the ice surface which washes the oil layer from under the ice to the recovery area.

Oil should be removed from the trenches and recovery holes on a continuous basis, to promote oil movement and prevent the oil layer from becoming too thick and being forced from the slot due to the increased pressure. In areas where the ice is too thin to allow manpower and equipment to work, the surface ice may be opened with the use of explosives and the existing oil pools burned. Regulatory approval must be obtained prior to using this method and precautions taken to prevent further damage to existing facilities (i.e. pipelines, tanks). If blasting is not feasible, the ice layer can be opened by dropping large objects such as rocks through the ice using a helicopter. Oil will surface in these holes where it can be burned. Heat generated by burning will induce a capillary action causing the oil to move to the burn area.

The containment and recovery of oil which is mixed with broken ice is the most difficult of all the cleanup procedures on open and moving waterbodies. This is due to the tremendous force which is exerted by the ice layers and the safety hazards which are involved. Oil will not flow freely within the ice mass, therefore methods to separate the two phases must be used. In most cases, an open area will have to be created where the oil can migrate or be directed so that recovery can be carried out.

Depending on the magnitude of the spill, the area or volume of ice and waterbody involved, various procedures can be used which will assist in containment operations. These methods are very dangerous and a decision to "do nothing", at least temporarily, is often a necessary choice. In extreme circumstances, there is no safe and technically sound method for containing and recovering the oil.

5.0 EVALUATION OF RESPONSE CAPABILITY AND PREPAREDNESS

This section provides a synopsis of the oil spill contingency plan questionnaire and the scenario responses:

Part A: Oil Spill Contingency Plan Questionnaire

Part B: Scenarios

Scenario #1: Oil Well Blowout
Scenario #2: Production Tank Overflow
Scenario #3: Major Pipeline Rupture - Urban Area
Scenario #4: Major Pipeline Break - River Crossing

Scenario #5: Storage Tank Rupture
Scenario #6: Ship Loading Terminal
Scenario #7: Truck Rollover
Scenario #8: Heavy Oil Spill into Creek

Each scenario is presented with comments (quantitative when possible) in the subjects of communication, contingency planning, logistics, equipment, training, research and development, policy and the current state of preparedness. The detail of the summary is dependent on the particular scenario and the respondents for that scenario. Some respondents were definitely more rigorous in reviewing company capabilities.

Each scenario response is indicated by:

- The "Actual Responses": The total number of survey responses received for the scenario.

- The "Applicable Responses": The number of survey responses for which the scenario was applicable in the respondent's operations. Percentage breakdowns contained in the summary are based on this number.

5.1 Oil Spill Contingency Plan Questionnaire

Questionnaire Response

Actual Responses: 56
Applicable Responses: 56

1) Have realistic worst case scenarios (product/volume/location) and impacts (environment/social and business) been reviewed for both oil and product spills?

Yes: 60% No: 40%

2) How often is the state of preparedness reviewed with staff?

At least once per year: 49%
At least once every few years: 29%
Never: 22%

3) Do all facilities have an oil spill contingency plan?

Yes: 55% No: 32%
Don't Know: 13%

The majority of oil companies belong to an oil spill cooperative that has developed and maintained a contingency plan. For this reason, many companies have not designed site specific plans but incorporate the oil spill function into drilling, sour gas and other emergency response plans. Forty percent (40%) of field personnel (usually from small companies) identified the local co-op plan as their response information source and 20% said the co-op would take over response efforts.

4) How often are the contingency plans reviewed with staff?

At least once per year: 23%
At least once every few years: 63%
Never: 14%

5) Can the initial notification procedures be improved?

Yes:	59%	No:	21%
Don't Know:	20%		

6) Are the contact names and phone numbers updated regularly (both internal and external)?

At least once per year:	24%
At least once every few years:	65%
Never:	11%

7) Do the plans' contact lists identify experts (both internal and external) who would be able to address specific environmental concerns (oil under ice, water quality, oil on moving water, agricultural)?

Yes:	61%	No:	23%
No Reply:	16%		

8) Do the plans identify government agencies who must be contacted?

Yes:	77%	No:	11%
No Reply:	12%		

9) Is there routine liaison with government agencies, emergency response personnel (police etc.) and residents in your area?

Yes:	61%	No:	21%
Don't Know:	18%		

10) Do the plans identify company policy on emergency spending limits and management decisions?

Yes:	36%	No:	55%
No Reply:	9%		

11) Have assessments been conducted of the oil spill equipment which is available for spill response?

Yes:	63%	No:	32%
No Reply:	5%		

12) Do the plans identify who is responsible for acting as the On-Scene-Commander (OSC)?

Yes:	82%	No:	16%
No Reply:	2%		

13) Has the OSC received the necessary training to respond properly to a major incident and has the OSC participated in training exercises? Is there a need to increase the OSC's training?

Yes:	50%	No:	50%

14) How often are in-house training exercises held?

At least once per year:	41%
At least once every few years:	9%
Never:	50%

15) Have the training exercises properly assessed the effectiveness of the personnel and the timely deployment of available equipment?

Yes: 59% No: 23%
No Reply: 18%

16) Have all personnel been instructed in their spill response duties, received the necessary training, and been involved in exercises?

Yes: 36% No: 59%
No Reply: 5%

17) Have the responses to these questions identified ways to improve the oil spill contingency plans and the response capability?

Yes: 65% No: 32%
No Reply: 3%

5.2 Oil Spill Contingency Plan Scenarios

5.2.1 Scenario # 1: Oil Well Blowout

Description

A development oil well is being drilled in mid-June on flat crop land. At 23:00 hours, a high pressure formation is penetrated and a kick occurs. Control of the well is lost and the well blows out at a rate of 100 m^3/day (600 barrels/day). There are undetermined injuries to the rig crew. It is 4 days before the well is brought under control. The well is located 70 miles from the nearest town where there are medical and oilfield services.

Scenario Response

Actual Responses: 42
Applicable Responses: 37

Communication

60% have effective emergency response communications and internal company notification procedures; the remainder thought that internal communication between drilling and production departments may need improvement. 90% consider reporting the incident to government as the highest priority.

Contingency Planning

70% of the responders had either a company or a co-op plan available. 70% also stated that the plan was adequate. 90% consider controlling the spill the most important step with environmental problems to be the least concern.

Logistics

50% were concerned with the isolation factor affecting the availability of manpower and equipment.

Training

50% indicated the need for more comprehensive spill training for drilling personnel.

Policy

20% did not know the company policy for blowouts. 50% would not comment if their internal policies were in need of change.

Current State of Preparedness

A blowout oil spill may be more difficult to control and shut-in than other oil spill sources. However, the containment and recovery operations would be similar. The industry is generally prepared to handle a blowout spill with the available equipment, contingency plans and expertise available. Prevention of such an occurrence has been addressed by recent changes in legislation, company operating practices and improved technology. However, 25% of the responders still felt that they were unprepared.

5.2.2 Scenario # 2: Production Tank Overflow

Description

The level control system on an oil field production tank (medium crude) fails on May 1st. The tank overflows at 01:00 hours and is discovered by a field operator 10 hours later. The appearance of the area around the tank indicates that the protective dike did initially contain the oil. However, as the dike filled, a section gave way. An estimated 10 m^3 of oil has left the lease. Heavy rains are forecast.

The lease is located in forested terrain 150 m away from a small creek. The creek joins a major river 800 m downstream. Both the creek and tributary are fishery habitats. There are also water users located along the river.

Scenario Response

Actual Responses:	43
Applicable Responses:	32

Communication

Responding companies have effective emergency response communications and internal company notification procedures. These functions are handled through a combination of individual company and oil spill cooperative contingency plans.

Contingency Planning

79% of the applicable responses stated they would use a cooperative plan to assist in controlling the spill situation. Individual company and oil spill cooperative plans are adequate and provide sufficient information to assist in spill response.

Equipment

The oil spill response equipment required to clean up a 10 m^3 spill is available through individual companies, oil spill cooperatives and industry associations.

Training

Although oil spill equipment training exercises are well attended, the scenario responses indicated the need for more comprehensive spill training with an emphasis on emergency response notification procedures.

Current State of Preparedness

Government regulations specify that all production tanks must be adequately contained by dikes. Facilities are checked on a regular basis. Equipment and level of training are sufficient to handle this scenario.

5.2.3 Scenario # 3: Major Pipeline Rupture - Urban Area

Description

A pipeline transporting condensate ruptures in a pipeline corridor near a residential area in October. The rupture, caused by a third party, is immediately noticed by the pipeline control centre and the line is remotely shut-in. The initial rupture and subsequent line drainage result in a total spill volume of 1500 m^3 over a 6 hour period. The oil has entered a residential area.

Scenario Response

Actual Responses:	44
Applicable Responses:	19

Communication

84% of the companies have effective emergency response communications and internal company notification procedures. The same 84% believe that their external communication networks are adequate.

Contingency Planning

84% of the companies have plans to cover the scenario of which 25% would use a company plan exclusively, and 50% would use a combination of company and co-op plans. 74% stated that the available plans would adequately address the scenario.

Less than 50% of the companies knew that their plan was updated regularly.

Logistics

74% believed that they could handle the spill logistics.

Equipment

Only one major company would rely totally on its own equipment. The rest would use a combination of co-op and company equipment.

37% felt available equipment was adequate and 32% believed that more equipment resources were necessary.

Training

Although oil spill equipment training exercises are well attended, 53% of the scenario responses indicated the need for more comprehensive spill training with an emphasis on emergency response notification procedures.

Policy

37% felt company policies did not address the scenario's urban aspect.

Current State of Preparedness

Evacuation procedures and public safety concerns have been firmly addressed in most

areas. Low and high pressure shutdown devices are available on most lines to shut-in the spill source immediately. Contingency plans contain the necessary information for contacting emergency organizations.

5.2.4 Scenario #4: Major Pipeline Break at River Crossing

Description

An April mudslide causes a pipeline to rupture at a major river crossing. Elevation drainage between control valves results in a loss of 3000 m^3 of crude oil over a 6 hour period.

Scenario Response

Actual Responses: 16
Applicable Responses: 10

Communication

65% indicated initial notification would be received through the control centre's alarm system with the remainder notified by the public. 50% felt that communications were adequate. Priorities for notification were (in order), the Company, the government, the public/police and last cooperative.

Contingency Planning

All respondents have plans to cover this scenario. 80% of the plans were identified as requiring a review with more information on control point identification/verification and environmental information.

Logistics

The most common logistical concerns were containment and recovery, high/fast water, control point selection and notification. Only one company was not able to sectionalize pipelines at major river crossings.

Equipment

Overall, equipment was considered adequate, effective and available. 20% would use company or private equipment. 75% would depend on co-op or other industry equipment.

Training

60% believe that they have adequate training programs.

Research and Development

Identified need to address techniques for high/fast water, solid and broken river ice, access in heavy rains and recovery techniques for various types of oil.

Policy

Most company policies place the response priorities in order of notification, spill response, and then environmental concerns. 20% stated that their company policy was in need of review.

Current State of Preparedness

Block valves are located at major river crossings. Under ideal environmental conditions, containment and recovery techniques exist. However, in abnormal conditions such as fast or ice infested

water, safe deployment techniques for equipment are not available.

5.2.5 Scenario #5: Storage Tank Rupture

Description

A storage tank containing between 1000 and 20,000 m^3 of crude oil collapses from a major structural flaw. The containment dikes are unable to withstand the force of the release and are washed away. The oil flows over the facility lease into the surface water collection system and off the lease into a gully that leads to a major river. The accident occurs at 21:00 hours in July.

Scenario Response

Actual Responses: 27
Applicable Responses: 19

Communication

Many large tanks do not have 24 hour supervision so initial detection of the failure would probably be reported by an outside party. Respondents showed a good understanding of proper communication procedures once they were notified of the incident.

Contingency Planning

All are covered by contingency plans that are judged to be adequate. Most companies have their own plans as well as co-op manuals.

Logistics

It is recognized that a very large spill into a major river could not be completely contained.

Equipment

Spill equipment is available from various companies and cooperatives.

Training

The most commonly stated concern was for more oil spill response training.

Current State of Preparedness

A major tank failure is a low probability event. There are few large tanks situated close to a river. However, the environmental consequences of this scenario would be very significant.

5.2.6 Scenario # 6: Ship Loading Terminal

Description

A transfer line at a ship (tanker) loading terminal ruptures causing a release of 200 m^3 of crude oil in a 10 minute period. Shoreline use in the area is a combination of natural, residential and industrial.

Scenario Response

Actual Responses: 1
Applicable Responses: 1*

* Only one CPA/IPAC company has a ship loading terminal for exporting Canadian produced crude oil.

Communication

Effective and tested notification procedures are in place to contact company and emergency response personnel and the Coast Guard.

Contingency Planning

Contingency plans have been developed to address all oil spill situations. Adequate for scenario. Environmental sensitive areas have been mapped and documented.

Logistics

The risk of fire and the effect on nearby resources are concerns that have been addressed. Tidal fluctuations may require backup containment boom to the standard boom placed around vessel during loading operations.

Equipment

Equipment is available from industry oil spill co-ops and the Coast Guard. Company relies on the rapid deployment of equipment from a marine industrial oil spill co-op. This decision has been thoroughly evaluated.

Training

All personnel have had training in equipment deployment and in the contingency plan contents. Supervisory staff have taken on-scene commander courses. The company regularly participates in equipment exercises.

Policy

Company policies are adequate to handle this scenario.

Research and Development

Research is required to determine the behaviour of heavy oil/condensate ends in marine waters. Conventional equipment may not be effective if the material approaches neutral buoyancy and sinks following evaporation of condensate from heavy oil.

Current State of Preparedness

Internal company policies have a strong bearing on how spills are handled. Environmental concerns can be addressed within company. All ships are boomed during loading operations.

5.2.7 Scenario # 7: Truck Rollover

Description

A contract tanker truck carrying your company's crude oil overturns in the ditch of a rural road. A hatch leaks 15 m^3 of crude oil. You are notified by provincial authorities 4 hours later.

Scenario Response

Actual Responses:	55
Applicable Responses:	53

Communication

This scenario is a common occurrence for both large and small oilfield operators. Most, if not all,

respondents have experienced such a situation. All the respondents felt that the communication systems in place were adequate. Most trucks are equipped with 2-way radios with backup from RCMP or other emergency response personnel to contact the oilfield operator.

Contingency Planning

All respondents felt that existing contingency plans were adequate or that no formal plan was needed.

Logistics

All respondents considered this scenario was a common occurrence that could be responded to quickly and easily cleaned up.

Equipment

The scenario responses indicated a need for tank truck hatch covers.

Training

The consensus of opinion was that experience is the best trainer, and because this was such a common occurrence, no extra training was required. However, some respondents recommended that tank truck operators should be involved with the oil spill cooperatives.

Policy

Some respondents were not aware that if a tank truck spills their product, they are responsible for the clean up.

Current State of Preparedness

The number of truck rollovers has increased in recent years. Many trucking firms have not received training on oil spill response. Equipment and procedures are adequate under most circumstances but as in the case of oil which enters fast or ice infested waters, recovery may be limited.

5.2.8 Scenario # 8: Heavy Oil Spill into Creek

Description

A well site transfer line ruptures resulting in 15 m^3 of heavy oil migrating off lease into a creek. The spill is discovered 2 hours later by a field operator.

Scenario Response

Actual Responses:	43
Applicable Responses:	31

Communication

95% of the respondents indicated that the notification procedures for their company were adequate. However, the sequence of what spill response procedures to implement first varied. Most companies felt that notification to company and government representatives would be done after the situation was under control.

Contingency Planning

The majority were aware of their company and oil spill cooperative contingency plans. Four companies indicated that they did not have

access to any type of plan. 80% felt that under general circumstances, the contingency plans were adequate. 50% wanted more information on the characteristics of heavy oil and specialized equipment and techniques which would be required for containment and recovery.

Logistics

Concerns were expressed on the access into the spill area, the presence of hydrogen sulphide and containment of oil which had migrated into the creek.

Equipment

Most companies were heavily dependent upon the oil spill cooperative equipment. 25% pointed out that specific equipment for containment and recovery of heavy oil was not available. 60% felt that standard equipment would work on this type of an oil spill and if all else failed, they would bring in equipment to dam the creek. There was an apparent "lack of knowledge" from most respondents as to what could be done under these circumstances. The majority also indicated that the equipment they had seen or used in the past was in good working order.

Training

All companies felt that training was very important and that the current classroom and field exercises were deficient when it came to the issue of heavy oil. Most companies send their employees to cooperative training exercises; however, most exercises deal with equipment deployment and response procedures. More emphasis must be placed on contingency planning manuals and their review with both field and management personnel. Overall, 90% indicated more training was required.

Research and Development

Respondents emphasized the need for a more complete understanding of heavy viscosity oils. 50% indicated more specific equipment and techniques for containment and recovery of these oils is needed and this information should be made available to all companies involved in heavy oil production.

Policy

20% felt that a more complete policy statement should be included in the plans and reviewed annually with response personnel.

Current State of Preparedness

75% of the respondents indicated that due to the size and nature of the spill, response procedures would be straightforward and that some form of containment and recovery could be implemented. The same procedures could be used for situations on land and into a slough or small lake. 75% felt efforts would be unsuccessful in this situation. This conclusion was not as optimistic if the waterbody had been a large river and if weather conditions were poor. The industries ability to contain spills which sink and move along the bottom of a deep river are non-existent and with current technology could only be monitored. Cleanup could be initiated when the oil surfaced or came into contact with shorelines.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The wide variety of onshore production and transportation methods for crude oil in Canada creates a continual challenge for industry to provide skilled manpower, specialized equipment and resource material to combat spills.

The onshore oil industry is prepared to handle incidents which occur on land and in small bodies of water. Manpower, equipment and contingency plans are available for both short and long term response situations. Company and industry associations are in place to coordinate spill response efforts, and these have proven successful in the past.

The industry is concerned with the containment and recovery of oil on fast flowing river systems especially during adverse weather conditions. The combination of equipment technology, volume and type of oil, and logistical factors such as time of year, land and water conditions, and accessibility create situations which may be extremely difficult, if not impossible, to handle. The technology for safe deployment of equipment during times of flooding or ice flows is limited and may never be available. For events such as these, the oil industry has developed strategies for communicating with those affected and would incorporate extensive monitoring and shoreline cleanup activities. Improvements in equipment, deployment techniques, and response training are required if industry is to expand upon the current state of preparedness to handle all types of oil.

6.1 Policy

Conclusion

1) Company emergency policy statements may not be specific to oil spill response. Individuals identified as oil spill responders must have a clear understanding of their responsibilities for response priorities, authority, training and financial expenditure.

Recommendation

1) Companies should prepare a clear and concise Policy Statement which is written into their contingency plans. The policy statement should include:

* A clear indication of the company's response priorities in the event of an oil spill. (ie: safety, property, environment etc.)

* Responsibilities for communicating with the public and media.

* An identification of company response personnel positions with a written mandate for oil spill response duties contained in their job descriptions.

* The necessary oil spill certified training required for company personnel and contract operators and a recognition of this training by senior management.

* The company's position on allowing personnel to perform duties for industry committees and oil spill co-ops.
* The government policy on the takeover and/or coordination of spill response operations.
* Strict procedures for the designation of on-call field personnel. There must be no confusion during an emergency response as to the availability of personnel.
* The liability exposure of company personnel.
* Crisis management procedures for handling worst case situations.
* The review of all significant industry spills with information available to all employees.

6.2 Prevention

Conclusion

1) Companies utilize oil spill prevention practices for drilling, production and transportation systems, however the onshore working group believes that these practices are not consistently applied in all operations.

Recommendation

1) Companies should conduct regular environmental audits of their facilities to determine potential spill sources so that preventative actions can be implemented. Proposed projects must also be assessed to ensure the incorporation of best practical technology in the planning phase.

2) The industry should evaluate the current level of leak detection systems available and where deficient, undertake a research and development program to improve their efficiency. For pipelines, companies should review the CPA's Pipeline Division upcoming report on leak detection methods used in the pipeline industry; and the Canadian Standards Association guidelines for leak detection systems.

3) Companies should implement an oil spill incident review process and incorporate the results into improved operating procedures.

6.3 Communications

Conclusions

1) Effective communication does exist between company departments (i.e. drilling, production, transportation) and their field offices, however this issue has to be continually addressed.

2) Procedures for government notification are confusing due to the number of regulatory requirements and agencies.

Recommendations

1) Companies must strive to maintain and improve regular communications between

all company departments, government agencies and the public to ensure that effective notification procedures are functional during oil spill response.

Companies should develop effective working relationships with local government agencies through regular communication.

The company name, facility name, location and emergency contact phone number, clearly visible for non-company personnel, should be posted clearly at all facilities.

The CPA should investigate the development of an internal industry newsletter which focuses on oil spill response and includes exercise dates, new developments and information sources.

Industry associations should develop and maintain active public awareness programs on oil spill response preparedness. Although some cooperatives do invite the media to training exercises, more effort should be made to focus public awareness on industry's capabilities.

2) Contingency plans should detail government organization structures and the necessary oil spill reporting requirements. For pipeline locations, the CPA should also encourage membership in the "Alberta 1st Call" or similar systems.

6.4 Contingency Plans

Conclusions

1) Companies felt that the contingency plans for onshore operations could be improved by including more information on specific facilities, urban areas and product characteristics.

2) The majority of companies rely on cooperative contingency plans which may not be specific to company operations.

Recommendations

1) Company and cooperative contingency plans must be updated annually and reviewed with management and field personnel in conjunction with simulation and communications exercises. The plans should follow an established industry standard for consistency and format and particularly address:

* communication procedures which must be implemented within company departments, with government and emergency response personnel.

* evacuation procedures and assistance from police and government emergency organizations, especially in urban areas.

* environmental resources, water and land users.

* characteristics, precautions and special recovery procedures for all products (condensate, diesel, gasoline and heavy oil.)

* preauthorization of response priorities and authority delegation.

* a plan review with emergency response personnel.

* documentation of response details for future training, cost control and legal implications.

* regulatory spill reporting requirements.

* requirements under the Transportation of Dangerous Goods Act for the notification of certain spills.

* the benefit of supplementing contingency plans with pocket size cards outlining emergency "First Hour Procedures".

2) Companies regardless of size and geographic area of operation, must identify their spill response procedures for all possible accident scenarios. This may identify shortcomings in manpower, equipment and supplies to deal with the scenarios. Procedures for some facilities should be included in existing cooperative plans.

The CPA must revise the industry oil spill contingency plan guidelines and oil spill information packages. (Estimated cost: $100,000 over next 2 years).

6.5 Equipment

Conclusions

1) Caches of equipment designed for containment and recovery of oil are maintained throughout Canada. The equipment is sufficient in most circumstances for conventional oils. However, in major river systems, under adverse weather and logistical conditions and/or in multiple spill situations the current available technology is insufficient to provide effective response.

2) The safety concerns associated with handling highly flammable light oils or condensates has required some equipment caches to contain specific equipment for this purpose. However, equipment for the handling of heavy oils will have to be developed.

Recommendations

1) Companies, cooperatives and industry associations should continue to work together to maximize equipment compatibility and effectiveness.

2) An evaluation of all equipment maintenance programs should be made to ensure effective operation.

3) Companies must evaluate site specific and remote locations for equipment requirements. In areas where there are

shortfalls, individual companies and industry associations should supply minimum equipment packages ($35,000/package).

4) Purchase additional equipment capable of handling light condensate and heavy oil products. ($3,000,000 over next 5 years).

5) Evaluate the feasibility of establishing a 1-800 telephone service for contacting the OSCAR and Coops equipment in Western Canada.

6) The National Emergency Equipment Locator System (NEELS) should be revitalized and upgraded on a regular basis.

7) Investigate:
* the standardization of boom connectors.
* the availability of tank truck hatch-cone covers.
* small equipment packages for tank trucks.
* the purchase of additional lake boom trailer by PROSCARAC.
* helicopter transportable equipment caches for remote locations.

6.6 Manpower

Conclusions

1) There are a large number of trained individuals who are capable of deploying oil spill equipment under most circumstances.

2) Only a limited number of trained individuals are available to manage initial and long term response in major spill situations.

3) Manpower is available through individual companies, oil spill cooperatives, industry associations and private contractors. mall companies do not have the manpower to adequately address oil spill response and would rely on other companies and the government for assistance.

Recommendations

A national directory of trained industry and contractor personnel should be developed and made available to response organizations to provide backup during major spill incidents. ($50,000 to establish).

6.7 Training

Conclusions

1) In Canada, oil spill equipment training exercises are attended annually by 3000 industry, contractor and government personnel.

2) The scenario responses indicated that certified training is required in spill prevention (improper "housekeeping" accounts for 20% of spills), contingency planning, control point selection, media relations, and environmental awareness. Industry has recognized programs available in these areas. (70% of responders indicated environmental

problems were the most difficult aspects to address in any of the scenarios.)

3) Companies do not adequately address in-house training on their own contingency plans and equipment. (60% of responders felt that they lacked confidence in this area.)

Recommendations

1) Local oil spill equipment exercises should vary in their location, time of year, and type of equipment. Site specific equipment exercises should be held by individual companies for their own staff in an effort to promote more "hands-on" activity. All training programs and equipment exercises should include members of the local emergency response agencies (police, fire, and emergency measures).

2) Companies must recognize that effective oil spill training is not limited to equipment deployment exercises but also spill prevention, contingency planning, control point selection, community relations, and environmental awareness. Companies must assess the oil spill response requirements of their personnel and provide the duties and responsibilities in the employee's job description.

3) Certification criteria must be developed for oil spill response training. All field personnel (including drilling and trucking) and management should have certified training.

4) Companies must encourage their employees' participation in oil spill committees, cooperative activities and training duties. Time commitments should also be identified in the employee's job description.

5) Overview training programs on planning and response must also be developed for senior management.

6.8 Research and Development

Conclusions

1) Industry has proven itself capable of conducting research and development projects on containment and recovery technologies. These efforts must continue in areas where industry has limited options available in worst case situations.

Recommendations

1) Guidelines and procedures must be developed for:
   * heavy oil
   * shallow and moving ice
   * fast flowing rivers
   * handling products with low flash points
   * cold weather equipment.

2) Evaluations must be made of the present communications equipment available through provincial telephone systems.

3) The CPA should encourage the re-establishment of dedicated equipment and training testing centres. An example is the U.S. Environmental Protection Agency's "OHMSETT" facility. ($500,000 over next 5 years).

4) The CPA should encourage the collection and publication of oil spill statistical data on a uniform and timely basis.

SECTION IV

SUMMARY AND GENERAL CONCLUSIONS

SECTION IV: SUMMARY AND GENERAL CONCLUSIONS

1.0 GENERAL CONCLUSIONS

A. Offshore Working Group

The Offshore Working Group concluded that blowouts in the Beaufort Sea could be adequately addressed with the industry's existing capability largely due to the light oil type and relatively calm seas found in the Beaufort Sea region. Technology and logistical support are available to contain and recover a large proportion of oil spilled even in winter, and the remainder is expected to evaporate and disperse or can be burned with little environmental harm, although sensitive coastal access would be difficult to clean up and would therefore have to be carefully protected. On the Grand Banks, however, the situation is less optimistic. Heavy seas, poor weather, and very waxy oil combine to make recovery and containment of oil from a well blowout exceedingly difficult. Current logistical support in the area is not sufficient to mount an immediate response to a major spill. Regional ocean currents will tend to take the oil northeastward into the Atlantic, thereby minimizing the threat to coastal areas of North America. The weathered oil will continue to disperse, evaporate and biodegrade during the long travel time before it reaches land. On the Scotian Shelf, evaluation of the condensate spill scenario indicates that the oil is so volatile that in a blow-out situation it will evaporate very quickly with no need for conventional containment and recovery. There is little environmental hazard associated with a condensate blowout in that area.

B. Onshore Working Group

The Onshore Working Group concluded that the industry is prepared to deal with most oil spill events that occur on land and in rivers and small bodies of water. Contingency plans, manpower and equipment are adequate for both short and long-term response situations. Company and industry associations are in place to coordinate spill response efforts, and these have proven successful in the past.

However, the range of activities and the complexity of the onshore industry (production, transportation and tanker loading) make it difficult to anticipate and plan for all the possible spill scenarios that could occur. The Onshore Group concluded that the key to achieving best response is **training**, so that personnel at the operational level are alert to potential and actual spill situations, knowledgeable, capable and able to move quickly in dealing with the many different types of spills that could occur.

The major area of concern is industry's ability to contain and recover oil from fast flowing rivers, under adverse weather conditions and especially when ice is present in the river. The technology for safe deployment of equipment with partial ice cover or during high water periods is very limited and may never be available due to the magnitude of the problem.

The rupture of a large storage tank or a large diameter pipeline involving light or heavy oil in a muskeg terrain is another situation where technology improvement is needed. Given these

technological constraints, industry's onshore response capability can best be enhanced by improving the training of front-line personnel.

2.0 SPECIFIC CONCLUSIONS AND RECOMMENDATIONS

In addition to the above general conclusions, the working groups also made some specific conclusions and recommendations in a number of areas that are integral to oil spill response.

A. Offshore Working Group

Oil Spill Response Equipment

Conclusions

* Large caches of equipment are maintained at various locations in Canada. Their usefulness depends on the type of equipment, the type of oil spilled, and the prevailing environmental conditions.

* As stated above, environmental conditions and oil type in the Beaufort Sea are conducive to equipment deployment, and expected oil recovery and response capability are relatively high although there is still a need to upgrade the type and amount of response equipment available. On the Grand Banks, where environmental conditions are more severe and oil is waxy, capabilities for recovery are very limited. On the Scotian Shelf, oil type (condensate) precludes the need for conventional containment and recovery as the product will dissipate extremely rapidly.

* Offshore industry co-ops are presently reviewing their response capabilities and will make recommendations for improvement where necessary.

Recommendations

* Offshore response capabilities should be consistent with the standards of best practical technology (BPT).

* To achieve BPT, industry co-ops and the Coast Guard should work together to maximize equipment compatibility and effectiveness.

Logistics

Conclusions

* **Ships.** In the Beaufort Sea region, an adequate number of vessels are presently operational during the open water drilling season and would be available to support an offshore response effort. On the Grand Banks, too few industry support vessels are available to mount an immediate response to a major oil spill event.

* **Tankage.** There is adequate tankage in both the Beaufort Sea and Grand Banks areas to provide offshore storage for recovered oil.

* **Aircraft.** Both regions have adequate aircraft support, and additional planes could be provided on short notice as required.

* **Accommodation.** Both regions have sufficient existing infrastructure to accommodate the numbers of personnel required (200 to 300) to mount a sustained offshore oil spill response. Shoreline response, where required, would need additional support, but sufficient time would be available to put this in place.

Recommendations

* A study should be undertaken to determine the availability of alternate support vessels (eg. Canada Coast Guard, DND, Fishing

Vessels) and to identify pre-arrangements required to ensure immediate access to these vessels in the event of a major spill.

Personnel Training

Conclusions

* In the short term, companies have an adequate number of trained individuals available to initiate and support an oil spill response effort. However, over the longer term of a sustained response effort, no single company has sufficient trained management and technical personnel to meet the requirements of an ongoing operation.

Recommendations

* Operators should identify the oil spill response training needs of the individuals listed in their contingency plans and ensure that the training programs are adequate and fully implemented.

* Emphasis should be placed on crisis management training for senior personnel and hands-on training for field staff.

Skilled Manpower

Conclusions

* Only a limited number of trained experienced personnel are available within any company to mount a major response in either the Beaufort or offshore east coast regions. For the initial stages of an offshore spill, additional response expertise and manpower would be accessed from regional industry co-ops, other oil companies and from government departments, such as the Canadian Coast Guard.

* Skilled manpower resources to support a larger scale, longer term response would have to be drawn from national, and where necessary, international sources. However, there is no established system for efficiently accomplishing this task.

Recommendations

* To facilitate the efficient acquisition of additional experienced offshore oil spill response manpower, a national directory of industry and contractor personnel should be developed and updated on a regular basis.

* Through the use of CPA member companies, rapid spill response support (RSRS) listings should be established for each of the active offshore operating areas. These listings would be comprised of industry personnel with necessary expertise to respond to various key technical aspects of a major oil spill event and could be contacted on short notice by a member company.

Management Systems

Conclusions

* The success of total oil spill response effort depends to a high degree on the strong commitment of senior management to be directly involved, informed and supportive during the event.

* Senior management will need the direct and full involvement of various other head office departments. These include legal, accounting, public relations, operations, response and environmental personnel.

Recommendations

* Senior management should participate in crisis management training and develop an

internal crisis management team involving all major departments.

* Crisis management plans should be developed and tested on a regular basis. Such plans should clearly define the roles, responsibilities, expenditure procedures and limits of senior management and key support personnel.

Government Approvals

Conclusions

* There are a number of areas (e.g. shoreline access, priority protection, dispersant use) where the requirement for government approval could significantly delay and hinder a spill response. Prior approval to use a variety of techniques would improve the operator's ability to carry out a rapid response effort.

Recommendations

* Memoranda of Understanding should be developed between industry and appropriate government agencies to identify areas of responsibility and cooperation during spill response efforts. A single window approach for interacting with government should be identified.

Research and Development

Conclusions

* The present state of development of best practical technology for dealing with major oil spills represents the result of millions of dollars of research conducted on a worldwide basis. Canada continues to be a world leader in the field of oil spill response research. The Canadian oil industry has played a major role in gaining this reputation by investing more than $30 million on offshore oil spill research over the last 20 years. However, in spite of this effort, they are still areas where further spill research is required.

Recommendations

* The major oil spill research and development programs funded by industry and government in Canada should continue to be supported at a higher funding level than has been the case over the last five years.

* Research and Development work should continue in the following areas:

  - clean-up of oil in broken ice environments
  - the development of more seaworthy booms
  - in-situ combustion of oil on water and in appropriate shore-zone area
  - improved technology for recovering heavy, waxy and/or emulsified oils
  - improved oil dispersants for cold water environments

PROJECTED COSTS FOR IMPLEMENTING RECOMMENDATIONS

1.	Oil Spill Response Equipment Acquisition to Achieve BPT	$4 to 6 million over the next 3 to 5 years
2.	Logistics Equipment Study (East Coast Only)	$20 K
3.	Personnel Training-Approximately $5 K/Individual x 40	$200 K/Operating Company
4.	Skilled Manpower	$50 K for National Directory
5.	Management Systems	Incremental to Existing Costs
6.	Government Approvals	Incremental to Existing Costs
7.	Research and Development Activity	$5 million over the next 5 years
	ESTIMATED TOTAL	$10 to 12 Million over the next 5 years

B. Onshore Working Group

Policy

Conclusions

* Company emergency policy statements may not be specific to oil spill response. Individuals identified as oil spill responders must have a clear understanding of their responsibilities for response priorities, authority, training, and financial expenditure.

Recommendations

* Companies should prepare a clear and concise Oil Spill Policy Statement that is written into their contingency plans.

Prevention

Conclusions

* Companies utilize oil spill prevention practices in their drilling, production transportation and tanker loading operations, however, these practices are not consistently applied.

Recommendations

* Companies should conduct an assessment of their facilities to determine potential spill sources so that preventative actions can be implemented.

* The industry should evaluate the current level of leak detection systems available and, where deficient, undertake a research and development program to improve their efficiency.

* Companies should implement a process to review and evaluate the events surrounding oil spills and incorporate the results into improved operating procedures.

Communications

Conclusions

* Spill communication procedures exist between company departments and their field offices, but this procedural area must not be taken for granted and should be exercised regularly.

* Procedures for government notification are confusing because of the number of regulatory requirements and agencies involved.

Recommendations

* Companies must strive to maintain and improve regular communications between all departments to ensure that effective notification procedures are functional during oil spill responses.

Contingency Plans

Conclusions

* Companies believe that contingency plans for onshore operations are adequate but could be improved by including more information on specific facilities, procedures in urban areas, and product characteristics.

* The majority of companies rely on cooperative contingency plans which may not be specific to company operations.

Recommendations

* Company and cooperative plans must be reviewed at least annually with management and field personnel in conjunction with actual simulation and communications exercises.

* Companies, regardless of size and geographic area of operation, must identify their spill response procedures and include these in existing cooperative plans. This would include the pre-authorization of response priorities and authority delegation.

Equipment

Conclusions

1) Caches of equipment designed for containment and recovery of oil are maintained throughout Canada. The equipment is sufficient in most circumstances for conventional oils. However, in major river systems, under adverse weather and logistical conditions and/or in multiple spill situations the current available technology in insufficient to provide effective response.

2) The safety concerns associated with handling highly flammable light oils or condensates has required some equipment caches to contain specific equipment for this purpose. However, equipment for the handling of heavy oils will have to be developed.

Recommendations

* Companies, cooperatives and industry associations should work together to maximize equipment compatibility and effectiveness.

* An evaluation of all equipment maintenance programs should be made to ensure effective operation.

* The equipment requirements of site specific and remote locations should be evaluated. In areas where there are deficiencies, individual companies and industry associations should supply the necessary equipment packages.

Manpower

Conclusions

* There is a large number of trained individuals who are capable of deploying oil spill equipment under most circumstances. Only a limited number of trained individuals are available to manage initial and long-term response in major spill situations.

* Manpower trained in oil spill clean-up is available through individual companies, oil spill cooperatives, industry associations and private contractors.

Recommendations

* A national directory of trained industry and contractor personnel should be developed and made available to response organizations to provide backup during major spill incidents.

Training

Conclusions

* Oil spill equipment training exercises are attended annually by 3000 industry, contractor, and government personnel.

* The scenario responses indicated that certified training is required in spill prevention, contingency planning, control point selection, media relations, and environmental awareness. Industry has recognized programs available in these areas.

* Some companies do not adequately address in-house training regarding their own contingency plans and equipment.

Recommendations

* Local oil spill equipment exercises should vary their locations, time of year, and type of equipment. Site specific equipment exercises should be held by individual companies for their own staff in an effort to promote more 'hands-on' experience. Local emergency response agencies should be encouraged to participate (i.e. police).

* Companies must recognize that effective oil spill training is not limited to equipment deployment exercises but also spill prevention, contingency planning, control point selection, community relations, and environmental awareness. Companies must assess the oil spill response requirements of their personnel and provide the duties and responsibilities in the employee's job description.

* Certification criteria must be developed for oil spill response training. All field personnel (including drilling and trucking) and management should have certified training.

* Companies must encourage their employee's participation in oil spill committees, cooperative activities and training duties. Time commitments should also be identified in the employee's job description.

Research and Development

Conclusions

* Industry has proven itself capable of conducting research and development projects on spill containment and recovery technologies. These efforts must continue to explore worst-case situations.

Recommendations

* Guidelines, procedures and research and development for equipment and response techniques must be developed for:
  - heavy oil
  - handling products with low flash points
  - fast-flowing rivers
  - shallow and moving ice
  - cold weather equipment

* Evaluations must be made of the present communications equipment available through provincial telephone systems.

PROJECTED COSTS FOR IMPLEMENTING ONSHORE RECOMMENDATIONS

1.	Contingency Plans	$100 K over the next 2 years
2.	Equipment	$3 million over the next 5 years
3.	Manpower	$50 K to establish national directory
4.	Training	Incremental to existing costs
5.	Research and Development	$500 K over the next 5 years
	ESTIMATED TOTAL	$3.65 Million over the next 5 years

3.0 SUMMARY

The above-noted, industry-wide, assessment of oil spill preparedness indicates that oil spill prevention and preparedness must continue to be the operational hallmarks of the Canadian oil industry. Recent events have forced a careful re-examination of the adequacy of these existing measures. Changes and improvements have been listed and evaluated herein with a view to accelerated implementation and deployment of oil spill containment and prevention systems. In some regions, oil spills from offshore drilling structures or into major rivers during spring breakup periods would be exceedingly difficult to contain and recover. These admitted difficulties could only be fully addressed through preventative measures. Nevertheless, the report highlights the essential need for a continued, even renewed, commitment by the senior managers of individual corporations to be directly involved in the decision-making process before, during and after possible spill events. The CPA, through its Environmental Code of Practice, has pioneered corporate principles needed to ensure that funds are sufficient to properly implement emergency response policies in Canada. This corporate commitment has been re-affirmed through the completion of this volume and through the ongoing dialogue of the CPA and IPAC with regulatory agencies and the public-at-large.

SECTION V

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1.0 LITERATURE CITED - OFFSHORE REPORT

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